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THE MANHATTAN BRIDGE ACROSS THE EAST RIVER, NEW YORK CITY: REVISED PLANS.

Something over a year ago, in our issue of Feb. 19, 1903, we presented sketches of a design for the new Manhattan bridge over the East River at New York City, worked out by the then Commissioner of Bridges of New York City, Mr. Gustav Lindenthal, M. Am. Soc. C. E., with the assistance of Mr. H. F. Hornbostel, for the architectural features. In a later issue (Dec. 10, 1903), the details of the engineering plans under this design, according to contract drawings which had been prepared, were quite fully illustrated and described. It will be remembered that the Lindenthal design was for a stiffened suspension bridge (of 1,470 ft. span) whose four main suspension members were to be chains made up of nickel-steel eyebars, while the stiffening element comprised these chains as upper chords, lower chords lying in the plane of the roadway at the center and thence sloping up to the towers, and a web-system connecting the chords. A great amount of discussion arose over these plans, carried on principally in the columns of Engineering News during the year 1903; the discussion centered on the question of whether wire cables or eyebar-chains were to be preferred as the suspension members of this bridge.

With the beginning of 1904, under a new municipal administration of New York City, Mr. George E. Best succeeded Mr. Lindenthal as Commissioner of Bridges, and the new commissioner selected Mr. O. F. Nichols, M. Am. Soc. C. E., as his Chief Engineer. The Manhattan Bridge problem was taken up anew, and a revised design was worked out. The firm of Carrère & Hastings, architects, of New York City, was retained for the development of the architectural part of the design.

The first results of this work have just come before the public, in the shape of sketch plans of the decorative features of the bridge, worked out by the architects. These sketches have been submitted to the Municipal Art Commission of New York City for its approval. A letter from Carrère & Hastings, accompanying the plans, gives an outline of the reasoning which controlled their work, as follows:

It is not our intention to enter into a discussion of the constructive features of the proposed bridge nor into matters of detail, but to give only in a very general way what seem to us to be the most important features in the designing of a new suspension bridge, from the architectural point of view.

If one were to cross the two existing bridges, the Brooklyn Bridge (No. 1) and Williamsburg Bridge (No. 2) without thought of architectural study or detail, one's attention would be strongly drawn to the impressiveness and charm of stone and iron, combined in the construction, as seen above the roadbed on the Brooklyn Bridge, and wanting in the other.

From the engineering and practical point of view it has been generally conceded to be a mistake to build the main towers of such a bridge of stone, because the openings in the towers must be so diminished in size in order to be made of masonry as to materially affect the circulation of such a thoroughfare. It is, therefore, impossible to obtain any effect of masonry above the roadbed by building the towers of stone. We have accordingly suggested that there should be some expression in stone above the roadbed of the immense amount of masonry necessary under the roadbed for the construction of the anchorage. On the one hand, this affords us an opportunity to bring stone construction in contact with the great amount of necessary iron construction, and on the other hand makes it evident to all crossing the bridge that they are on the anchorage by some other method than by the mere change in the pavement material.

When one thinks of such a bridge in execution rather than in mere drawings, one cannot help feeling how inadequate are any mere matters of architectural detail work in iron lost in such a forest of structural steel work. The first, and what seems to us, therefore, the most important feature in design is this stone work over the anchorage. This anchorage has an area of about 225 ft. in length by 175 ft. in width, and it has seemed to us that nothing could be more impressive than this court treatment (see Figs. 1 and 2 on following page.—Ed.) 120 ft. above the water level. This treatment of the anchorage has made it possible to obtain an extra width at this part of the thoroughfare and has given places off from the general circulation where people can rest under cover on their way over the bridge and obtain a view of the distant city and the surrounding waters.

We have endeavored to utilize the necessary masonry supports for the anchorage saddles to make them a part of the architectural scheme connecting the colonnade; one of the pavilions of the colonnade on either side of the anchorage is devoted to staircases which connect with the interior of the anchorages and which will be finally connected with the street.

The architecture of this anchorage as seen from the street is also one of the most interesting portions of the bridge to be treated, and it has been our endeavor to avoid any unnecessary ornament, using only structural decoration and obtaining our effects by the large masses of material and stone jointing. We have endeavored to concentrate all of our enrichment upon that portion of the anchorage which comes under the colonnade and which expresses an interior void.

That portion of the anchorage which does the principal amount of the real work we have endeavored to keep simple and calm in contrast with the other. One of the most interesting features in the study of the anchorage has been the study of the massive buttresses on the water side, which carry the saddles to receive the cables and which buttress the immense thrust given by those cables.

The perspective which we have submitted (Fig. 2 herewith.—Ed.) explains more fully than we can in writing what we mean by the relation of a mass of stone to the iron work over the roadbed; this also shows the court which we believe will be the most impressive feature of the bridge, and will be money better spent than by spreading detail over so large a construction.

As to the towers: We were very much impressed by the beauty of the lines given us by the engineers, which are the expression of an economic and mathematical construction; these lines in themselves are most beautiful and need but little decoration, and such decoration should in our opinion be concentrated, and accentuate in every way the lines of the construction. Here we have another opportunity afforded us to obtain covered resting places on the way over the bridge, and at the same time, by making an iron and copper hood, to enrich and obtain a shadow at this point. Another and most important feature from the architectural point of view is the crowning of these steel towers. It is our opinion that any mere decorative treatment on top of these towers and above the cables, coming against an open sky and on so large a construction, would be at best inadequate and undignified. It has therefore been our endeavor to simply crown them with a cornice effect and to keep this crowning under the lines of the cables, like the cap of a column under an architrave. This cornice we have tried to make iron in character, with a large projection and concentrating all decorative features in a gallery effect the whole width of the tower.

The main lines of the cables and suspended trusses as given to us by the engineers are in our opinion the most beautiful we have ever seen in any bridge, expressing

GENERAL ELEVATION OF MANHATTAN BRIDGE OVER EAST RIVER, NEW YORK CITY; REVISED PLANS.

Mr. Geo. E. Best, Commissioner of Bridges; Mr. O. F. Nichols, M. Am. Soc. C. E., Chief Engineer; Carrere & Hastings, Architects.

as they do the rational and simple solution of the problem from the engineering point of view.

June 22, 1904. Carrère & Hastings.

Of the sketches submitted with this letter we have reproduced the greater part, sufficient to exhibit in detail the results of the architects' work. The sketches also indicate the main features of the design of the structure itself, the engineering part, although detail drawings will not be ready for some time to come.

The important elements of this design, as compared with the Lindenthal design and with the Williamsburg and Brooklyn bridges, are the following:

4. The stiffening trusses are parallel-chord trusses in the level of the roadway, as in the Brooklyn and Williamsburg bridges. The Lindenthal design had its stiffening trusses along the suspension chains.

5. The large halls in the anchorage of the Lindenthal design are omitted.

THE COMPRESSED AIR POWER TRANSMISSION PLANT OF THE CLEVELAND STONE COMPANY.

By Lucius I. Wightman, E. E.*

The most recent application of compressed air power to transmission purposes on a large scale is found in the plant recently installed for the Cleveland Stone Co. on their quarry property near North Amherst, O., about 30 miles from Cleveland. Work was begun on the plant in July of last year. The system, covering the ground as originally intended, has been in operation since the early part of this year, but extensions are now under way which will mean an increase of about 50% over the original scope of the enterprise. The present installation handles the output of the Gray Canon Quarry, the largest sandstone quarry in the world (Fig. 1); but the air lines are being extended to supply power to two neighboring quarries. The system is a typical example of the modern idea of a centralized and economical power plant replacing a number of scattered units operating at low economy and under unfavorable conditions. The results achieved in four months of operation have been almost startling, and seem to merit a detailed description of the means by which they were secured.

Outlined briefly, the plant consists of a central air compressing plant, from which power is distributed by means of air pipe lines to the various machines throughout the quarry. The system retains the same quarry machinery which was formerly operated by steam generated in a number of isolated boiler plants.

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The power house is a brick and steel structure, located on a spur of the Lake Shore & Michigan Southern Ry. at a point near the center of the group of properties owned by the company at this place. A fire wall divides the interior (Fig. 2) into the boiler room, 34 × 69½ ft., and an engine room, 63½ × 69½ ft., inside dimensions.

The floor of the engine room (Fig. 3), of steel and concrete construction, is elevated 9 ft. above the boiler room level, leaving a basement which contains the condensation pump, condenser piping and some other auxiliaries. The condensers and inter- and after-coolers are also located on this level, extending into the engine room above through openings in the floor. Access to the boiler room is secured through a fire door on the basement level. The interior of the engine room is painted white, and large windows on three sides secure exceptionally good ventilation and lighting. The chief engineer's office on the engine room floor commands a view of the entire machinery installation. The location of the building is such that future extensions may be made by additions on the west side.

The main engine foundations, built of the sandstone from the quarry, are fine examples of masonry foundations. Heavy connecting walls bind the two sections together, and a heavy cement cap on the top makes a practically solid unit. The main engine frame is bedded to a depth of about 2 ins. in the cement cap. Heavy plates bedded in the cap support the steam and air cylinders, and any movement due to expansion and contraction simply causes the cylinder feet to slide on these plates.

Coal storage capacity for 650 tons is provided in bins on the north side of the power house, served by an elevated siding, from which hopper-bottomed cars discharge direct. The bins extend the full length of the boiler room, and openings in the wall admit the coal direct to the floor in front of the boilers. Fuel is delivered by hand from the floor to the stoker hoppers, and ashes

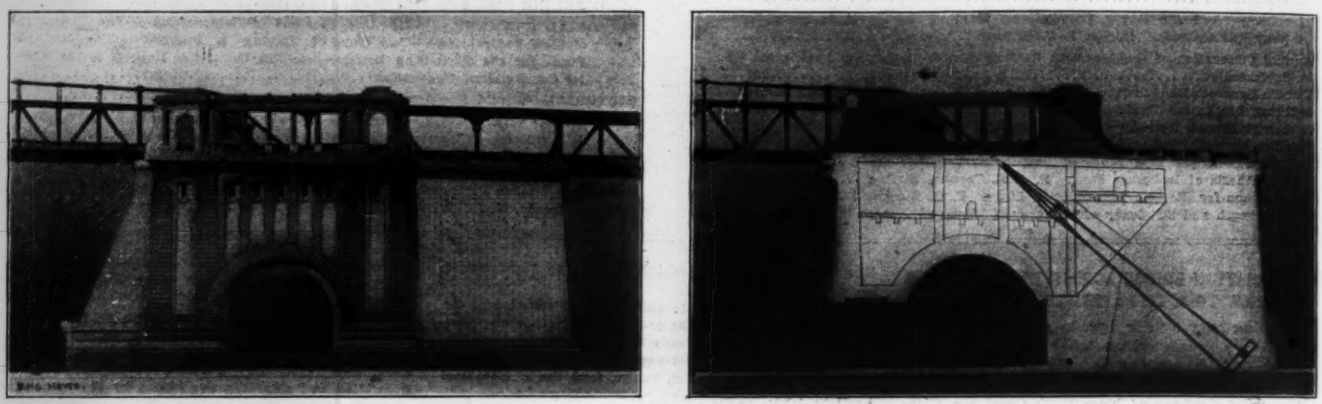

FIG. 1. SIDE ELEVATION AND LONGITUDINAL SECTION OF ABUTMENT AND ANCHORAGE OF THE MANHATTAN BRIDGE; REVISED PLANS.

1. Wire cables are used for the main suspension members, as in the Brooklyn and Williamsburg bridges. The Lindenthal design had eyebar-chains.

2. The towers consist each of four steel posts of compact design, one under each cable, set in a transverse row and braced together. They are closely similar to those of the Lindenthal design, with two important differences; they are fixed at the bottom, and bear cable-saddles on top, the cables being continuous over the saddles. The Lindenthal design provided a pin-bearing at the bottom of each tower-post, and had the suspension-chains connected by a pin at the top. In the Williamsburg bridge each tower consists of a pair of latticework steel towers braced together. In the Brooklyn Bridge each tower is a massive stone pier pierced by a high arched opening for the roadway.

3. The roadway of the shore spans is carried directly by the cables. This is also the case in the Brooklyn Bridge and in the Lindenthal design for the Manhattan Bridge. In the Williamsburg Bridge the cables are loaded only over the main span, the shore portions of the cables being merely back-stays. The roadway of the shore spans in that case is carried by longitudinal trusses resting on a support intermediate between tower and anchorage.

FIG. 2. VIEW ALONG ROADWAY OF MANHATTAN BRIDGE FROM APPROACH, SHOWING ARCHITECTURAL DEVELOPMENT OVER ANCHORAGES; REVISED PLANS.

are removed in barrows to a dump outside. The size of the plant did not justify the installation of coal and ash handling machinery, as the boiler room force would not be reduced thereby. As additions are made, a point will be reached where the expenditure will be justified, and this refinement will then be added.

The boiler plant (Fig. 4) includes three water-tube boilers of 257 HP. rated capacity, designed for 180 lbs. pressure. The extension of the system to supply the two neighboring quarries, not originally provided for, will necessitate the use of a fourth unit of the same size, which is now being installed. The boilers are set in batteries of two. Mechanical stokers are used, driven from a common jack shaft by a small vertical engine located between the two battery settings. Mechanical-induced draft is furnished by a 90-in. fan, driven by a small horizontal engine; this equipment doing the work of a 250-ft. stack at an original cost of about one-fifth that of a natural draft installation. Automatic regulating valves control the supply of steam to the fan engine and maintain the boiler pressure within a few pounds on either side of the normal. The breeching is raised to provide a free passage in the rear of the boiler settings, where much of the auxiliary piping is placed, and leads directly, with no turns, to the fan elevated on a steel framework to the level of the engine room floor. The 60-in. stack extends but a few feet above the roof. A high degree of combustion within the firebox is indicated by the fact that smoke is rarely seen rising from the stack, except when fires are being cleaned. High and low water alarms are furnished on each boiler, the water level being also automatically controlled.

Water for boiler feed and condensing purposes is secured from an abandoned quarry distant about a quarter of a mile from the plant. A direct-acting plunger pump, located at the water's edge, and driven by compressed air from the plant, delivers water to a storage tank near the power house through 1,600 ft. of 3-in. pipe. This tank or reservoir is of stone, cement-lined, and its capacity of 750,000 gallons assures a reserve sufficient to operate the plant for some days.

Analysis of the supply water showed the following proportions of solid matter:

	Grains per U. S. Gal.
Calcium carbonate	4.89
Magnesium carbonate	2.68
Calcium sulphate	2.96
Sodium chlorate	.65
Sodium carbonate	.66
Total solid matter	11.84

This analysis suggested the advisability of providing some system for removing the scale-forming substances from the boiler feed water. An open exhaust steam or primary heater is installed in the boiler room, elevated well above the feed pumps. This receives the exhaust steam from feed and circulating pumps, and from fan and stoker engines. A relief valve communicates between the heater and an atmospheric exhaust pipe. Valves are provided by means of which the heater may be cut out for inspection and cleaning, the auxiliaries discharging direct to atmosphere. A closed live steam or secondary heater is erected above the boilers, taking steam direct at boiler pressure. A hot well below the basement floor receives a portion of the main condenser discharge, the water level in the well being maintained constant by a float-controlled valve. The temperature of the condenser discharge varies with that of the condensing water from 80° to 120° F. A circulating pump takes the feed water at this temperature from the hot well and elevates it to the primary heater, where its temperature is raised to 210° to 212° F. From the primary heater the feed water flows by gravity to the boiler feed pump, which lifts it to the secondary heater, where it is raised to a temperature corresponding to boiler pressure. From the secondary heater the purified water flows by gravity into the boilers. An automatic regulating valve in the feed pump steam supply pipe keeps the water level in the boilers practically constant. A regulating valve in the steam pipe to the circulating pump controls the delivery of water to the primary heater. That the purifying system is effective is shown by the fact that repeated examinations of the boiler tubes have failed to show any scale whatever. The secondary heater has been cleaned once, after operating three months, and the upper elements were found heavily encrusted with scale-forming matter. The primary heater has thus far shown no appreciable deposit of solid matter. The company's locomotives are also supplied with boiler water from this central purifying system, delivered to a tank on the tracks. The value of this arrangement will be noted later in these lines.

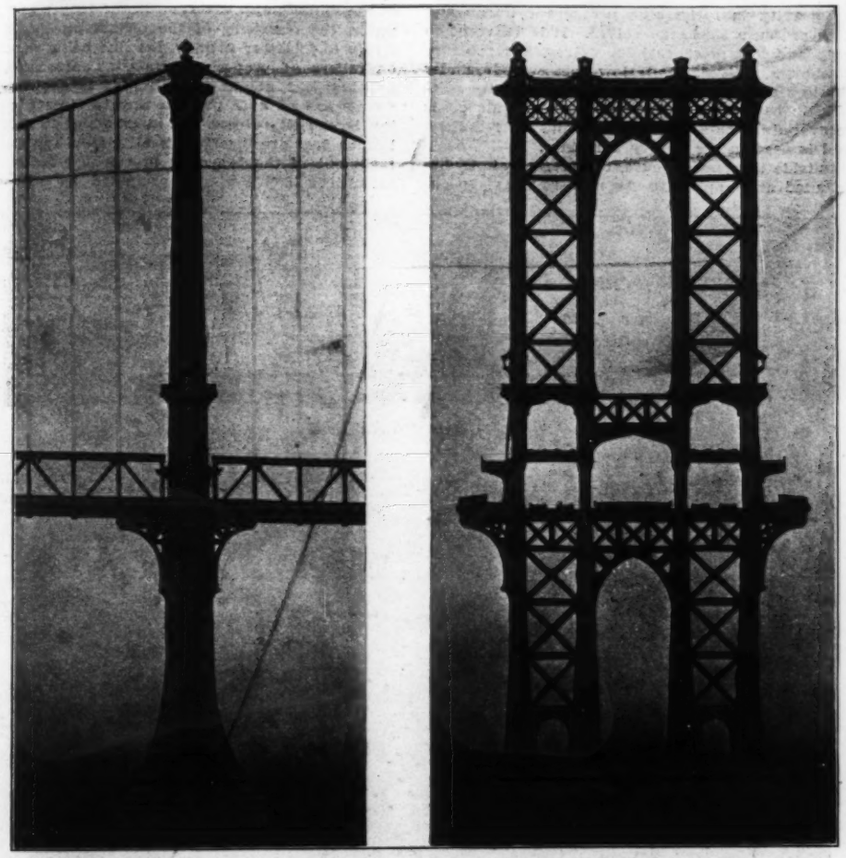

FIG. 3. ELEVATIONS OF A MAIN TOWER OF THE MANHATTAN BRIDGE; REVISED PLANS.

The boiler feed pumps, installed in duplicate, are of single outside-packed plunger pattern. The circulating pumps are of standard duplex plunger type. All pumps are direct acting, and are grouped with draft blower and primary heater at the east end of the boiler room.

The functions of the two circulating pumps are distinct, though the arrangement of pipes and valves is such that they may be interchanged. One normally handles the boiler feed water during the first stage, as described above. The other takes water from the cold well and circulates it through the air cylinder jackets and inter- and after-coolers of the main compressor units, discharging into the storage tank. Arrangements are also provided whereby the primary supply pump at the distant quarry may on occasion circulate its discharge through the air cooling system, thus leaving free one circulating pump.

Jet condensers are used, each main unit having its individual condenser, driven by steeple compound engines. The steam to each condenser engine is drawn through the tubes of the reheating receiver of its main unit, passing through a steam separator before entering the cylinder. The exhaust is discharged into the receiver and does further duty in the low pressure cylinder of the main engine. The condensing water at 60° to 80° F. is raised by the condenser vacuum from the cold well, communicating directly with the storage tank. The condenser discharge flows by gravity to the cooling system outside. Oil eliminators remove all oil from the exhaust before it enters the condensers.

The cooling system is of novel construction. It was adopted in lieu of a cooling tower to save the power required by the latter in driving the fan and elevating the condenser discharge.

It consists of three sets of trays, of matched Louisiana cypress, each tray broken into riffles, and the three set in tiers above the storage tank. A slight pitch is given each tray. The condenser discharge empties upon the higher side of the upper tray, is distributed over its length in a channel, and flows in thin sheets and cataracts to the lower edge. It falls to the tray below, where the operation is repeated, thence to the third tray, over which it flows into the tank below, making its fourth passage through the reservoir to the cold well. The arrangement gives about 30,000 sq. ft. of cooling surface, and the maximum air cooling effect is secured without any expenditure of power. The drop in temperature over the trays ranges from 20° to 40° F., depending upon the air temperature and humidity.

Steam piping throughout the power plant is of extra heavy pipe and fittings, with the exception of the main steam header, which is of gun metal. The steam riser from boilers to purifier and header, and steam pipes from header to engines, are made up with wide sweep bends instead of elbows. The system of valves and duplicate piping is developed to give all possible assurance against a shut down from the failure of any part of the piping. All pipe above 3 ins. is made up with flanged fittings. Gate valves are used in all cases except for throttles. All live steam piping and boiler feed pipes are covered with 85% magnesia covering.

The main units of the compressor plant are steam-driven, cross-compound condensing two-stage Corliss air compressors (Fig. 5), built by the Ingersoll-Sergeant Drill Co., of New York. The steam cylinders are 20 and 44 ins. in diameter; air cylinders 24¼ and 39¼ ins. The common stroke is 48 ins. At normal speed of 90 revolutions per minute, each compressor has a low pressure piston displacement of about 6,000 cu. ft. of free air per min., and at 100 lbs. air pressure indicates about 1,000 HP.

The usual fly-ball governor is supplemented by a governor piston, normally balanced in a vertical cylinder between after-cooler pressure on one side and weights on the other. The governing operation is as follows: At normal air pressure this piston maintains the steam cut-off at the proper point; when the air pressure falls below normal, the weights lower the piston and operate a rod which lengthens the cut-off, speeds up the compressor and restores the pressure; when the pressure rises above normal, the piston rises, shortens the cut-off and the speed is reduced until normal pressure is attained. It is noticed that either of these operations is followed by a gradual restoration of cut-off to almost normal value, though the speed of the compressor remains proportional to the demand for air. The device is simple, quick and positive. Air pressure is maintained constant within close limits. The fly-balls become operative only when the standard speed of 90 revolutions is exceeded—as when an air line should break or other sudden and abnormal demand be made upon the system. The usual safety device is provided for shutting down the compressor should the governor belt break.

The air valves, inlet and discharge, are of the Ingersoll positive air-thrown type, two inlet and two discharge valves being carried on each cylinder head. A piston on each valve stem is operative within a small cylinder in the valve bonnet, carrying on one side standard air pressure, on the other a reduced pressure of about 1 lb. The lower pressure opens the valves at the proper time—the higher pressure holds them to their seats. The admission and release of high pressure air to the valve cylinders is controlled by a small independent slide valve device operated through a reducing motion from the main piston rod. There is no "chattering" of the valves, and indicator cards show none of the familiar irregularities in intake and discharge lines. The diagrams are practically ideal.

Air washers at the mouth of the low pressure intake conduits of each compressor serve the double purpose of keeping out from the cylinders the grit from the grindstone mills, and of cooling the intake air. Each washer contains 600 vertical tubes, set in a box or tank with their lower ends submerged about 2 ins. in water. This water is constantly changing, the supply coming from a tank on the hillside above. The intake air is drawn into the upper ends of the tubes, down through the water and into the containing tank and intake conduit. Every particle of dust held in suspension is removed. Furthermore, the pasage of the intake air at, say, 85° F. through water at 55° F., means a material saving in fuel. For every 5° F. reduction in temperature of intake air gives an increase of 1% in capacity and efficiency of compression. The slight loss in friction of air through tubes and water is negligible.

The intake conduit of each compressor is 28 ins. square in cross-section. The low pressure discharge to inter-cooler is 16 ins. in diameter; high pressure intake from inter-cooler and high pressure discharge to after-coolers are of 10-in. pipe. Steam and exhaust pipes are 7 and 14 ins. in diameter, respectively. Receiver separators are introduced in the steam pipe next to the throttle. The percentage ratio between air valve and cylinder areas is unusually great. The reheating steam receiver, as mentioned above, is heated by the live steam to the condenser engine, and receives the exhaust from this engine as well as the discharge from the main high pressure cylinder. This system of reheating, the method of handling the condenser exhaust, and the unusual cylinder ratio in the main units combine to secure in these two-cylinder engines economy closely approximating that of the triple expansion engine.

A slate gage board at each compressor carries gages indicating the following normal pressures: Steam, 165 lbs.; air, 80 to 83 lbs.; inter-cooler, 23 to 25 lbs.; receiver, 5 lbs; vacuum, 26 ins. A revolution counter is also mounted here, and the daily air output of each compressor is recorded, and checked with the weighed coal and metered boiler feed water.

Each compressor unit has its individual inter-cooler and after-cooler, of vertical type. A 14-in. air header delivers the after-cooler discharge to the primary receiver. A tank in the basement receives the condensation from the entire steam piping system and a pump returns it to the boilers. Condensation from the steam heating system is trapped into the hot well.

The oiling system throughout is automatic and most complete, extending even to the sight-feed lubricators on the pumps. Gravity lubrication of bearings is secured from an elevated tank—the waste oil collecting in a chamber and being passed through an oil filter in the basement to the supply tank above. Each steam cylinder has its individual oil pump, supplemented by a hand-pumping device. The air cylinder oil is carried in a supply tank under receiver pressure, from which it flows by gravity into the high pressure cylinder and high pressure discharge valves. It is delivered to high and low pressure inlet valves, low pressure discharge valves, and low pressure cylinder through reducing valves furnishing pressure suitable in each case. About 75% of this air oil is recovered in the drains of inter- and after-coolers, and is used in the quarry machines.

Outside the power house, compressed air is distributed and applied to the numerous uses peculiar to quarry work—drilling, channeling, hoisting, pumping, driving gang saw mills, grindstone mills, machine shop, forge fires, etc. As is usual where a new power is adopted, unexpected uses are being found every day.

FIG. 1. LARGEST SANDSTONE QUARRY IN THE WORLD, CLEVELAND STONE CO., NORTH AMHERST, O.

The removal of the moisture entrained in the compressed air was one of the most vital problems to be solved, as dry air is one of the first requisites in expansive engines. The inter-coolers and after-coolers receive the first and second precipitations of entrained moisture and are regularly drained. The air header discharges into the primary receiver, 66 ins. in diameter by 18 ft. long, and here again moisture is accumulated and withdrawn through the drain cock. From the primary receiver the air lines grade to secondary receivers. The lines beyond these secondaries are also laid to drain back to them. These secondary receivers catch any moisture which may have passed the earlier separators. In operation it has been found that the air delivered to the cylinders of the machines is remarkably dry.

The air pipe distributing system has been worked out to a fine degree of perfection and as an example of careful engineering is worthy of special note. As the zone of activity in a large quarry is constantly shifting, the problem confronting the engineer was that of making available, at any point over a large area, the full power of the system, with a minimum investment for material and minimum liability to vital breakdown. The accompanying diagram, Fig. 6 shows how this problem has been solved. The air piping has been laid out in a five-loop system and a consideration of the diagram shows that the maximum volume of compressed air is available on any one of the lines, without excessive drop in pressure, while any line or section can be cut out for repair or alteration without crippling any other part of the system. The loop arrangement gives a great carrying capacity at low pipe cost. Expansion and contraction are provided for by off-setting the line one pipe length every 400 ft. These 400-ft. sections are anchored at the middle: any variation in the length is taken up in the elasticity of the off-set pipe, without strain to joints or fittings, the line being mounted on rollers at proper intervals. The location of primary and secondary receivers is shown. All valves are of gate pattern and in sizes above 6 ins. have rising stems. At intervals of 40 ft., 3-in. branch tees are inserted in all mains, for the attachment of the branches to working faces. All main line loop tees are protected by valves in their three branches. Whenever air connection to a main is made at a "motion" or working face, a 3-in. riser is brought to the floor level opposite the derrick and connected by a 10-ft. length of hose to a 2½ × 2½ × 3 in. tee; branches of the tee are protected by valves and serve for the attachment of a 2½-in. secondary header with 2-in. flanged branches every 6 ft. This header may be extended, flexibility being secured by inserting flexible joints on the laterals next to the header. The hose to each machine ends in a flanged coupling by which it is attached to the header at any of the branch tees. The wear falls upon the threads of bolts, easily replaced, instead of upon the pipe threads, and leaks at these local connections are avoided by this precaution. The air piping system was installed under a guarantee to hold full working pressure for 12 hours, and to stand the same test at the end of a year. The guarantee has so far been sustained. No leaks have been discovered. Air gages, accurately calibrated and interchanged, have shown no measurable drop in pressure at any point on the distributing system. The ample receiver and pipe capacity absorbs all fluctuations and the pressure maintained at the power house is available at every working face.

Reheating is employed at hoist and mill engines and is being extended to all air motors. A very simple and effective stationary air reheater has

been devised, being a few turns of pipe laid in a brick setting and heated by a small coke fire. The average cost of these reheaters, in labor and material, has been $35. A surprisingly small quantity of coke is required, the cost of present application not exceeding $1 per day. The air is heated to 280° to 300° F., and no trouble has been found in lubrication of cylinders. On some of the channeling machines the old boiler is temporarily retained, connected into the air line and serving as an air reheater by the use of a small coke fire on the partly covered grate. More compact and efficient reheaters are being devised to replace these boilers and for all cases where a portable device is required. No attempt is yet made to reheat the air for the drills.

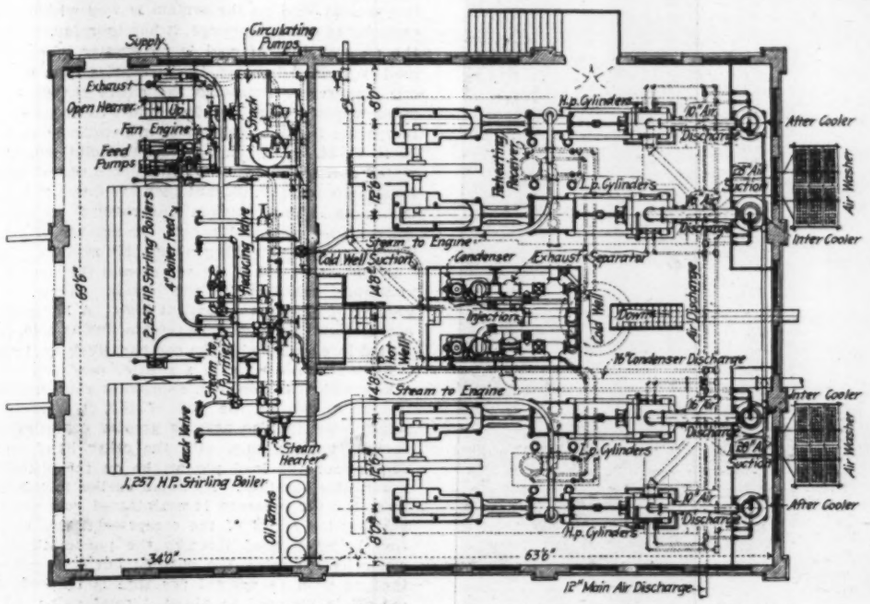

FIG. 2. PLAN OF COMPRESSED AIR POWER PLANT, CLEVELAND STONE CO.

The only instance of the use of steam for power outside of the main plant is found in Mill No. 1, where 11 gang-saws are driven by a 175-HP. tandem compound condensing steam engine. The location of this mill adjacent to the power house permitted the operation of this engine at highest economy with steam from the main boilers, and with the full benefit of expansion secured by connection with the main condensers in the power plant. Mill No. 2, about a half mile distant from the power house, contains 5 gang-saws driven by an 80-HP. engine supplied with air through one of the stationary reheaters described above. Scattered at different points over the workings are five direct-acting plunger pumps, all at present driven by air without reheating, and performing maximum duty. Compressed air is also used in numerous blacksmith forges, in operating the steam hammer, and in driving a grindstone mill and machine shop. The present aggregate load on the plant, in mill and hoisting engines, channelers, drills, pumps, forges, etc., is about 850-HP.; while the average combined indicated horse-power of the compressors is at this time about 675. The central boiler plant has replaced 31 isolated boilers, aggregating 1,200 B. H. P., which were usually overtaxed. The distributing system is now being extended to supply power to two neighboring quarries about a half mile south. When these extensions are completed the total number of boilers replaced will be 49, aggregating close to 1,800 B. H. P. So far as possible all these abandoned boilers are piped into the system as local receivers. The power supplied to the two neighboring quarries will be applied to operate a 175-HP. Corliss engine driving a 6 gang-saw mill besides 7 channelers, 6 drills, 4 hoists, 3 pumps, and machine shop, forge fires. A novelty in the distributing mains to these two quarries is the use of light casing with Hammond couplings instead of standard pipe. Natural gas transmission practice has been followed, at a cost for a given carrying capacity of about two-thirds that of a standard pipe line.

One of the most interesting features of the installation described is the fact that no special appliances were introduced for the application of the new power. The machinery already operated by steam under the old system was simply overhauled—the cylinders rebored, rods turned, glands packed and clearance reduced—and attached to the air lines. The cut-off on the expansive engines was in some cases shortened to ⅝. Experiments now under way indicate that reheating may be carried to a much higher degree than has yet been attained. It is believed that temperatures as high as 500° to 700° F., may be used, without attaining a mean cylinder temperature which will cause trouble in lubrication. It is believed that in many cases cut-off can be reduced to give terminal pressure at atmosphere. The amount of coke required in reheating is almost negligible. Even with the present reheaters, the cost of reheating fuel for the entire system is less than $1 per day, and as reheaters are developed and perfected, still higher fuel economy will be obtained.

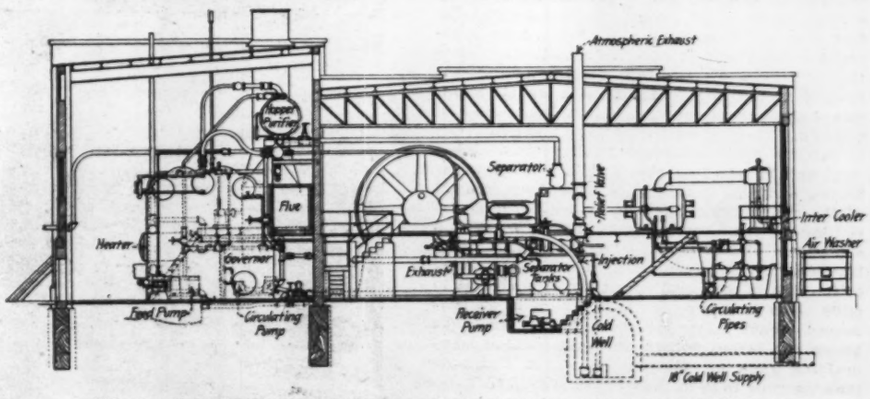

FIG. 3. ELEVATION OF COMPRESSED AIR PLANT, CLEVELAND STONE CO.

The plant was started Jan. 2, 1904, in the midst of a blizzard, with a temperature 15° below zero. Starting under these inauspicious conditions, it has since been operating night and day without shut-down or interruption due to the failure of any link in the system. The two "bogies" which have hitherto frightened all adventurers into the field of pneumatic power transmission—freezing of air engines and low efficiency—have been effectively and permanently disposed of. The successful operation of the plant, without one shut-down or loss due to freezing, shows how effectively this evil has been prevented by the complete elimination of moisture from the compressed air. Reheating is used for its added economy, but the plant has been operated repeatedly under all weather conditions without reheating. The installation of reheating devices has been gradual and is not yet complete. The following figures furnished by the Cleveland Stone Co.'s chief engineer show that the second evil has been removed. The table is a rough comparison of average daily fuel and labor charges against the power system, during the months of April, 1903, operating with steam, and April, 1904, operating with compressed air.

	April, 1903. 50 tons run-of-mine		April, 1904. 15½ tons slack.	
Coal consumption	at $2.00	$100.00	at $1.60	$24.80
Labor and attendance:	16 machines		12 machines	
At channelers	at 10.00	160.00	at 10.00	120.00
	15 machines		9 machines	
At drills	at 3.00	45.00	at 3.00	27.00
Firemen:				
At hoists ...9 men	at 1.25	11.25		.....
At pumps and boilers* ..2 "	at 1.25	2.50		.....
At No.2 mill†2 "	at 2.00	4.00		.....
Boiler repair gang		5.00		.....
Locomotive repair and rental		10.00		.....
Coke for reheaters		.....		1.00
Total daily charges, labor-fuel		$337.75		$172.80
Daily saving in labor and fuel by compressed air				$164.95

*Drill boilers.
†12-hr. shifts.

On this basis the total saving in a year of 300 days, in fuel and labor, is $49,485.

The reduction in the number of channeling machines and drills operated in 1904, noted in the above comparison, is due to the fact that the heavy and uniform air pressure, always available, enables these fewer machines to do more than the work formerly done by the larger number, when operating under the lower and fluctuating pressure of steam. It is assumed that the charges for oil and waste were the same in both months—an assumption which is not borne out by the facts, which indicate a very great reduction in these charges in 1904. No charges were made in 1903 for the labor and attendance at Mill No. 1, as the same force was required in 1904 at the power house. The coal consumption is a matter of absolute record. In 1903, run of mine coal was used, delivered to 31 boilers, and broken, scattered and wasted in cartage. In 1904, slack coal was used, handled at minimum cost. The item of boiler repairs is based upon the fact that under the old system, with isolated boilers and local water, one boiler maker and assistant were constantly retained to keep these boilers in repair. Prior to the introduction of the compressed air plant, the company's locomotives were out of commission one month in the year, undergoing repairs and general overhauling. During this month the company was compelled to rent other locomotives from the railway. This rental, together with the cost of repairs, brought the average daily charges against these machines to $10. Under the present system the locomotives draw their feed water from a tank supplied from the purifying system in the power house. Their boilers are now perfectly clean inside, and to date no charge has been made against them for repairs.

Another fact worthy of note is that the steam plants replaced by the new system were in most

cases operating under conditions of average fuel and steam economy. The boilers at the hoists were of good tubular type, in standard brick settings and well housed. The steam pipes to the engines were in no case more than 15 ft. long. The same conditions existed at Mill No. 2. The channelers carried their own boilers, of standard locomotive type, and the steam pipes were not over 6

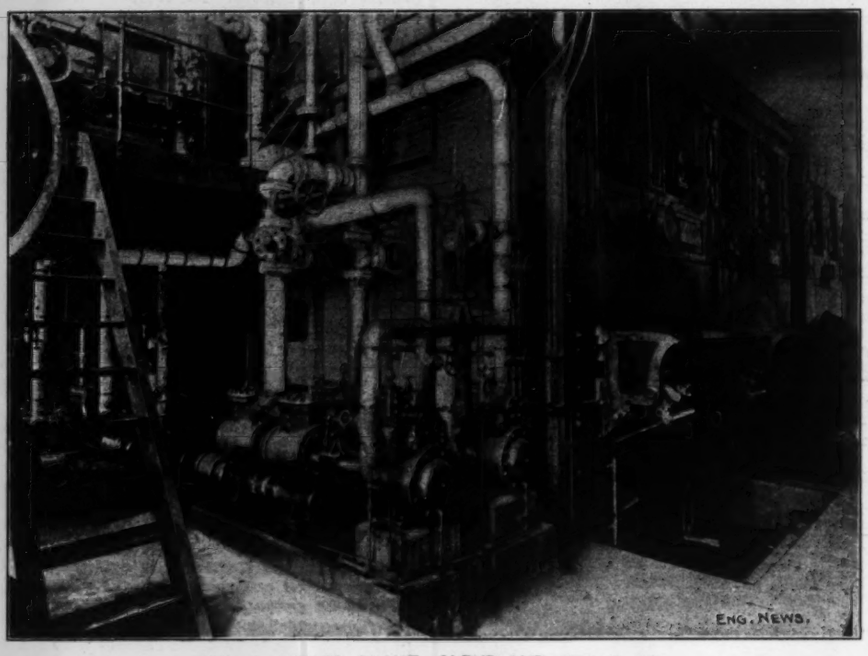

FIG. 4. BOILER PLANT, CLEVELAND STONE CO.

ft. in length. About 85% of the steam used is accounted for by these boilers. Yet even with these favorable conditions of fuel economy, the saving in coal consumption has been as indicated in the table above.

This tabulated comparison is a statement of fact, but it fails to bring out two points of vital importance; the output of rock in April, 1904, was much greater than in April, 1903, and this increased output was secured with the total labor force reduced over that of 1904 by about 75 men. Figuring these men at the average daily wage of the quarryman, the daily saving just shown is brought up to about $275. This result is due to several causes, chief among which is perhaps the fact that a full working day of 10 hours is secured under the most effective conditions. When the whistle blows the full working pressure is secured at the turn of the throttle and is maintained throughout the day. There is no delay at starting. There is no fluctuation in pressure due to careless boiler attendance. There is no labor employed in wheeling coal and in moving water barrels and pipe to keep pace with the movement of the channelers. There is no smoke or steam settling in the quarry, darkening it, making a short day shorter, and interfering with rapid hoisting. There is no steam to wet the clothing of the men in cold weather, no smoke and heat to stifle them in warm weather. There is no condensed steam in the pipes and cylinders to be blown out before operations begin. There is no draining gang to empty the pipes at night, no thawing gang to open them in the morning. There is no time lost in banking fires or waiting for coal. Heavy air pressure, everywhere uniform, drives every machine to the limit.

Furthermore, the use of the new power has improved the character of the quarry output. Under the old system, with coal and ashes scattered over the working floors, the water from rain or snow found its way through the coal or ash pile, over the surface and down the sides of the rock, staining and discoloring it. With smoke from the boilers filling the quarry, the exposed faces were quickly covered with a dark deposit. Since air has been used, these effects have disappeared, and the rock quarried presents a clean sparkling surface.

The introduction of compressed air has made conditions so pleasant that old men are eager to remain, and the best class of new labor is attracted. A stimulating effect is felt by the entire working force, and there is noticed a vim and push and cheer which was not present under the old arrangement. The value of these features cannot be stated in dollars and cents, but it is certain to run into the thousands in the course of a year.

The plant was installed under a most rigid guarantee of fuel consumption; it being guaranteed to furnish aid to operate the machines at that time maintaining the quarry output, with a daily consumption of coal not to exceed 17 short tons. The guarantee has been more than sustained under daily working conditions established without formal test. The average daily consumption of coal, as shown above, was, in April last, 15.5 short tons.

A feature of special interest is the fact that in operating the plant there has been found to be no appreciable "peak load" during the day. The compressors maintain almost a uniform output. Fluctuations in load are small and gradual. The explanation of this lies in the immense storage capacity secured in primary and secondary receivers, in the pipe line itself, and in the old boilers which have been connected in as auxiliary receivers at different points on the system. This steady load is in great contrast to the daily load on an electric power distributing system, where no storage capacity can smooth out the irregularities in the load curve.

Another most interesting development has arisen in the operation of the main units. While the present load on the system is well within the capacity of one compressor, it has been found that the consumption of coal is no greater when the load is divided between the two units than when one compressor furnishes the entire output. In other words, it has been found just as economical to operate the two main units in parallel at about 30 R. P. M. as to run one at 60 revolutions. As stated earlier, the normal rated speed of the compressors is 90 R. P. M., but they are found to have the same efficiency when underloaded, as when fully loaded at rated speed. A number of conditions combine to bring about this result.

In the steam end of the compressor the losses by radiation, inherent in the steam engine, are greater at slow speed than at high. A low piston speed allows the steam to remain during a longer period in contact with the comparatively cool cylinder walls, resulting in a greater condensation—a loss which is, however, somewhat recovered by re-evaporation at the end of the stroke. Low steam velocity also permits greater condensation in the steam piping. On the other hand, in a compressor the load per stroke on the piston is practically constant. As noted earlier in this article, the air pressure is maintained constant by varying the speed of the compressor, this variation being secured through the pneumatic governor by changing the cut-off; but it is noticed that as soon as normal pressure is reached, the cut-off is restored to about normal value, while the speed remains proportional to the load. This means that the steam end is operating all the time at cut-off of practically maximum economy.

In the air end of the compressor, light load and low piston speed means that the air during the process of slow compression is in contact with the cylinder walls, and consequently subject to the jacket cooling action, during a longer period. The cooling water is more effective in removing the heat of compression, a given volume of water being required to absorb a smaller quantity of heat. These conditions result in nearly isothermal compression and the indicator cards from the air cylinders of these machines show a compression line closely approximating the isothermal.

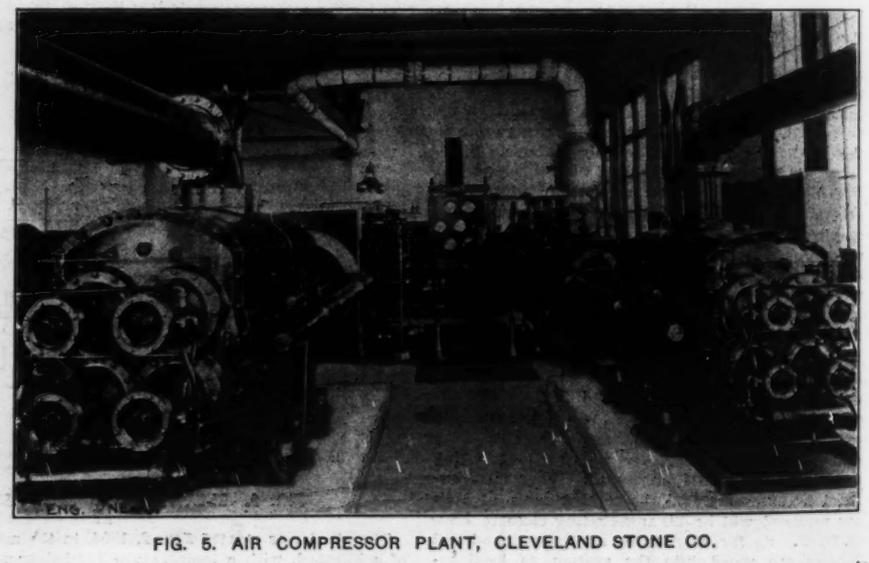

FIG. 5. AIR COMPRESSOR PLANT, CLEVELAND STONE CO.

The friction load on the compressor unit is proportional to the speed. A consideration of all of the above items on both sides of the account shows a balance between conditions in the air and steam ends of the units resulting in efficiency practically uniform at all loads.

A parallel consideration of the electric driven

unit shows the disadvantages under which it must operate. A constant speed must be maintained, meaning a constant maximum friction load. The engine operates at most economical cut-off only at full load. When underloaded, it uses shortened cut-off, meaning excessive expansion and a lower mean cylinder temperature, with increased condensation loss. Not only is the steam engine operating at lowered efficiency under light load, but the same is true of the generator. The total efficiency of the unit is the product of these reduced efficiencies, and diminishes with the load.

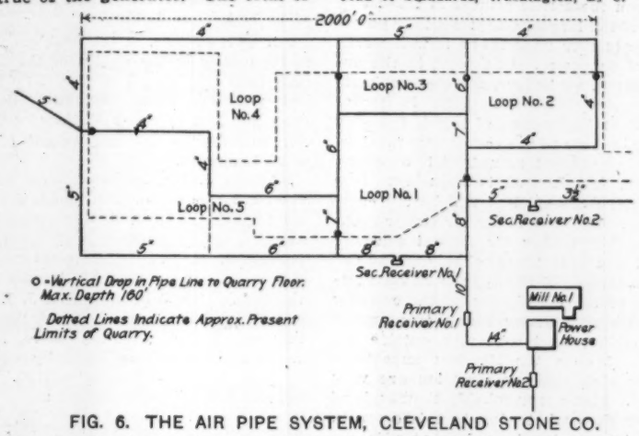

FIG. 6. THE AIR PIPE SYSTEM, CLEVELAND STONE CO.

There is at present being introduced in the works at North Amherst a system of records and cost keeping which will charge against each department of the plant its individual expense, and show the cost of each productive operation. When the distributing system is extended to the south quarries (not contemplated in the original scheme) a detailed test is to be made along approved lines of engineering practice. When this test has been made, and its results worked out in connection with the recorded productive costs, a comprehensive statement of the operative economy of the system can be made. Such parts of this statement as would be of interest to the engineering public may appear later in these columns.

The plant was designed and installed complete for the Ingersoll-Sergeant Drill Co., of New York, under the personal supervision of Mr. George R. Murray, Manager of the Cleveland and Pittsburg offices of that company.

THE SUBSTITUTION OF CHEAPER CEMENT in constructing the New Orleans drainage works has been passed upon by the courts. On May 23 the jury commission of the United States Circuit Court rendered a verdict in favor of the New Orleans Drainage Board, for $28,300, with legal interest from judicial demand until paid. The object of the suit was for the reimbursement of the difference in price between the high-grade cement required by the specifications for the sewerage and drainage work and the inferior cement which was substituted by the National Contracting Co. The contract for the work was awarded in 1897, and as it was to be of a permanent character, it was required in exact terms to be of the best quality of Portland cement possessing specified qualities when submitted to tests usual for determining the quality of cement. Soon after the work of construction was begun the drainage commission's chief engineer, without consultation with the drainage board, made arrangements whereby a cheaper cement was substituted by the contract for the specified cement, adding largely to the contractor's profits, but with no reduction of price or corresponding benefit to the drainage commission. When the facts were learned and the charge brought to the chief engineer he made a confession of its truth and exonerated the commission of any knowledge whatever regarding the substitution. He sought to justify himself upon the plea that he had exercised his professional judgment and had given the commission a better cement than was called for by the contract, and that what the city got in quality should compensate it for any difference in cost.

A LONG-SPAN CANTILEVER BRIDGE will soon be built across the Rhine at Ruhrort, Germany. Its main span has a center to center distance of 667 ft., of which the suspended span is 443 ft., and the cantilever portions 112 ft. each. The side spans are 417 ft. and 390 ft., respectively, between pier centers. Each side span cantilevers 55 ft. toward the shore, and carries a suspended shore arm 218 ft. long, making the shore span between pier and abutment 273 ft. long. The total length of the bridge, between end shoes, is 2,020 ft. The bridge is 82 ft. deep between chords, over the two main piers. The central suspended span has a curved top chord, making the truss deepest at the center (46 ft.). The central opening of this bridge will be the largest bridge span of Germany. The structure is to be built by the Gustavsburg Bridge Works, whose design was awarded first place in a competition for the crossing.

THE STANDARDIZATION OF PYROMETERS is the subject of a bulletin recently issued by the National Bureau of Standards, Washington, D. C. The bulletin discusses briefly the availability of different forms of high-temperature measuring devices, and notes what elements are included in the standardization tests which the bureau will carry out on request. A list of fees for the work is also given.

AN INTERESTING EXHIBIT will be made at the St. Louis Fair by the associated Westinghouse Companies of this country and Europe. It may be a surprise to many to learn that there are no fewer than 19 separate corporations controlled by the Westinghouse interests in the United States, most of which are located in or near Pittsburg. There are also 7 foreign companies, ranging in location from Canada to Russia. These 26 companies are making a united exhibit at St. Louis, and in connection with this they will show a series of "moving pictures" of scenes in and about the Westinghouse works. The interior views of the works were taken in a novel manner: The mutoscope camera was placed on a platform suspended some fifteen feet above the ground from an electric traveling crane running lengthwise of the shop. About fifty feet ahead of this crane, a battery of Cooper-Hewitt vapor lamps was suspended from another crane, the two cranes being moved at equal speed down the shop aisle. The crane carrying the lamps also carried a 25-KW., 125-volt direct-current generator, driven by a 500-volt motor. Sixty-four vapor lamps were used, hung in frames in sets of eight. Each frame was about 5 ft. high, 3 ft. wide, and 4 ins. deep, and took 35 amperes at 110 volts. The whole bank of lamps consumed 30 to 40 KW. of power. The pictures were taken at the rate of 15 per second. In addition to views in the machine shops, foundries, forge shops, testing-rooms, etc., views were taken of the procession of employees leaving the works when the whistle blows, of the 20-mile panorama along the Pennsylvania R. R., between Pittsburg and Trafford City, etc.

THE VARIATION OF CRUSHING STRENGTH of concrete with the size of the test cube has been investigated recently at the Royal Testing Laboratory at Gross-Lichterfelde-West, Berlin, Germany. It was found that the size of cube is of very material influence on the observed unit strength; the breaking strength was highest for the smallest cubes, and decreased regularly with increasing size of cube. The test specimens were respectively 7.1 cm., 10 cm., 20 cm., and 30 cm. (1.8 ins., 2.5 ins., 5.1 ins., and 7.6 ins.) on a side. The crushing tests were made at ages of 7, 28 and 90 days. One series of tests was made on fairly dry concrete, having 11% of water, while the other was made on a very dry mixture, 7.5% of water. The reduction of unit strength with increasing size was more marked with the dry cubes. The concrete was in all cases made with an aggregate of rather fine unscreened gravel, in proportion of 1 cement to 4 of aggregate, by weight, and was seasoned in water. The results of the work are fairly represented by the following series of figures, giving the results on the "wet" samples, molded in tightly-jointed molds. The figures are quoted from the "Centralblatt d. Bauverwaltung" of June 4, 1904:

Crushing Strength of Concrete Cubes of Different Sizes, in Percents of Strength of 1.8-in. Cubes.

Concrete: 1 of cement to 4 of tank gravel, by weight, and 11% water. Not rammed in molds.
Seasoned: 2 days in air, remaining time in water.

Age in days.....		7	28	90
Size of cube		76.6	118	188 kg. per sq. cm.
7.1 cm. = 1.8 ins.		660	1,020	1,630 lbs. per sq. in.
		100%	100	100%
10	2.5	100%	99%	98%
20	5.1	78	83	82
30	7.6	71	76	73

Note.—The percentages are separately figured for each age of test.

A BAD RAILWAY ACCIDENT occurred on the Wabash Ry. near Litchfield, Ill., on July 3. An excursion train bound from Chicago to St. Louis went into a siding through a switch wrongly set, and was wrecked by colliding with a freight train standing in the siding. At least fourteen persons were killed outright, and many were seriously injured. The railway officials believe that the switch was broken open and thrown by some one with malicious purpose.

A DISASTROUS OCEAN STEAMER WRECK off the Hebrides on June 28 caused the loss of nearly 700 lives. The steamer "Norge" of the Scandinavian-American Line, on a voyage from Copenhagen, Denmark, to New York, with emigrants, struck Rockall Reef, several hundred miles off the west coast of Scotland, while out of her course. The vessel carried about 800 persons on board, and only 145 survivors reached land. The "Norge" was an iron vessel 340 ft. long, 40 ft. broad and 25 ft. deep, built at Glasgow in 1881.

A TRAIN BLOWN FROM THE TRACK is reported from Petersburg, Ill., on July 5. A passenger train from Chicago to Springfield, Ill., on the Chicago, Peoria & St. Louis Ry., met a tornado near Oakford, a few miles west of Petersburg, at 6.30 p. m. of July 5, and was rolled down the low embankment. One of the trainmen was killed, and many of the passengers were injured.

FIG. 7. SHOWING REHEATER MOUNTED ON CHANNELER.

SUBMARINE TORPEDO BOATS are now being rapidly constructed for the navies of all the leading powers. England has 9 completed and 20 in process of construction. France has 33 in service and 40 under construction. Germany has 6, Russia is supposed to have 4, Italy has 4 and the United States has 9.

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ADVERTISING RATES will be furnished upon application. "Want" and "For Sale" notices (special rates), see pages 26-27. The pages for new "Want" "Proposal" and "For Sale" advertisements are held open until Wednesday noon.

Thomas Tredgold's famous definition of engineering as "the art of directing the great sources of power in Nature for the use and convenience of man" forms the subject of a critical inquiry recently sent to us by a well-known engineer. He asks what sources of power Tredgold referred to and why he omitted to specify them. What should we of the present day understand as the true interpretation of this definition?

In answer to our correspondent's inquiry it seems to us that the historic definition deserves interpretation in a large and liberal way. Strictly speaking, for example, electricity is not a "source of power" in the same way that a waterfall or a coal mine is; yet it is as truly a source of power—power to do things and to compass useful ends—as is the power of steam or of the water wheel.

Very likely Tredgold had in mind when he penned his famous definition only the forces of winds and waterfalls and the energy stored in steam; and the harnessing of these forces to serve mankind. But no such narrow interpretation is necessary at the present day. Engineering is the art of directing the great sources of power in Nature, and all that has to do with that direction is engineering. At first sight, for example, this definition might seem to omit the work of accurate measurement as practised by the civil or the mechanical engineer from the field of engineering. On reflection, however, we see how the art of measurement of great areas is a necessary part of the work of applying Nature's powers to transportation in the construction of railways or to the development of power directly in a hydraulic plant; or in another field, without exact measurements in the machine shop, the whole art of constructing mechanism to utilize Nature's powers would be impossible.

Again, there is no need to give a narrow interpretation to the term "directing." The engineers who build levees to protect the Mississippi Valley from floods are "directing" the great powers of Nature for man's benefit, as truly as those who utilize the falling water on the river's tributaries to drive mills.

On the whole, therefore, we are inclined to believe that Tredgold's definition of engineering can well be interpreted to cover engineering at the present day. At least it deserves to stand until some better one is presented.

In these days of general power distribution by electricity the public, and perhaps the engineering profession also, is apt to forget that in certain situations hydraulic or pneumatic power distributing systems may have advantages over electricity. Both these systems are undoubtedly less heard of than they were 20 years ago when the electric motor was in its infancy, and it is quite possible that for that very reason their advantages are less familiar to engineers than ought to be the case.

For this reason the article printed in this issue, describing one of the largest compressed air power distribution plants ever undertaken is well worth the attention of engineers. One point in the article which deserves, we believe, especial emphasis is the careful engineering work evident in its design. An excellent illustration of this is the care taken to supply cool air to the compressor intakes. Every engineering student nowadays is or ought to be taught that the cooler air is when taken into a compressor, the more efficient will be the compression process. Yet how many air compressors are running to-day taking air from inside the engine room at a temperature probably 20° to 40° higher than outdoors? If the appeals of the compressor builder or the intelligence of the erecting engineer produce any better result it amounts merely to extending an intake pipe outside the engine room and even the simplest expedients for cooling the air before compression are very seldom adopted. There are probably thousands of air compressors at work to-day in this country, in mining districts or elsewhere, located adjacent to a flowing stream or spring of cool water; and nobody realizes that a little stream of water applied to cool the air before its passage into the compressor would be the equivalent of a stream of fuel flowing into the coal bin all the time the compressor is working. Such a system need not be complicated or expensive. It may be made in many different ways other than the one described by our contributor in another column; and however made if it only lowers the temperature of the entering air, the results can hardly fail to be beneficial.

It is possible that one reason why pre-cooling of the supply to air compressors is so seldom done is the dread of the "practical" man in charge that the air may be moistened. Of course moisture in the air is one of the chief troubles with which users of compressed air have to contend; but by proper arrangement of the cooling apparatus, it should be possible to draw the air into the compressor not only cooler but dryer than ordinary air. It will be remembered that the capacity of air to hold moisture rapidly falls off as its temperature is reduced. By subjecting the entering air to direct contact with cool water, the moisture will be condensed and caught by the water.

Of course we do not mean to say that pre-cooling the entering air can avoid the necessity for providing against trouble from condensation after compression; but with a properly arranged precooler the difficulties on this score should be lessened instead of increased.

What is the best method of solving a problem? More often than not it happens that a problem can be solved in two or more different ways, and opinions frequently differ as to the best method to use. It occasionally happens that the student is compelled by an instructor to solve problems by a long and roundabout method when a simpler one would serve as well, and the reason given is that he thus obtains mental exercise. Whatever be the merits or demerits of this plan, the student should not form the habit of solving his problems in this way, or when he undertakes actual work he will frequently find himself distanced by the "practical" man.

In our opinion the simplest and most direct solution of a problem is always the best, not only because it saves time but because it involves fewer chances of error in the result.

This subject is brought before us by an anonymous letter just received, and we break our customary rule by printing it, as follows:

> Sir: Referring to "Notes and Queries," in your issue of June 16, is not the following a better solution of the problem presented by "A. K.," regarding the effective weight of a cubic foot of immersed concrete weighing 125 lbs. in air, and having the capacity to absorb 20 lbs. of water? Assuming as you state that the pores in the concrete affect its weight exactly as if they were concentrated in a single cavity, then this cavity, capable of containing 20 lbs. of water would equal in volume 62.5 ÷ 20 = .3125 cu. ft., leaving .6875 cu. ft. as the volume of solid material per cubic foot of concrete. This would displace 62.5 × .6875 = 42.97 lbs. of water, which is the weight lost by immersion. Therefore the effective weight of the immersed concrete equals 82.03 lbs.
>
> Respectfully yours, J. L. D.
> New York, June 27, 1904.

Our own solution of the problem was merely to add mentally to the weight of the concrete in air (125 lbs.) the weight of the 20 lbs. of water, and subtract from the sum the weight of the cubic foot of water displaced (62.5 lbs.), leaving 82.5 lbs. as the net weight of the concrete when immersed.

Whether J. L. D.'s solution or our own is the "better," the reader can judge for himself. As we remarked above, in our opinion the simplest solution of any problem is the best, and we have printed J. L. D.'s letter merely because it furnishes such an admirable illustration *why* it is the best. It will be seen that J. L. D.'s final result is 82.03 lbs. instead of 82.5 lbs., and by looking over his computation above, it will be seen that he obtained this result by writing:

$$62.5 \div 20 = .3125.$$

When he should have written:

$$20 \div 62.5 = .32,$$

in which case he would have obtained the correct answer, 82.5 lbs.

If there be engineering students who are diligently studying higher mathematics while they remain deficient in arithmetic, we trust that our unknown correspondent's letter may teach them—or their instructors—a useful lesson.

New designs have been completed for the Manhattan Bridge across the East River at New York city. As will be seen from the engravings published elsewhere in this issue, they provide for a structure totally dissimilar in character and appearance to the bridge previously planned. About the only thing in common between the work of the two designers is the attention paid by both toward securing a structure of artistic beauty. It is quite safe to say that a comparison of the two designs by the artist and architect will develop partisans for each and between whom a word would precipitate a controversy. This, it seems to us, would be both an ungracious and an idle task in the present light of things. The bridge, whose design we picture, will undoubtedly be built substantially as it is at present planned, and the main question that concerns the public is whether its design as presented is susceptible of improvement and if it is, then, how this improvement can best be made. For the general lines of the structure only words of approbation are possible. They are strong and graceful throughout, and it is worthy of comment that they remain unchanged as they came to the architect from the engineer. Still considering the general view, it was, we think, a happy thought on the part of the architects to emphasize the presence and purpose of the anchorages by raising a massive parapet wall above the roadway on each side. Another point that is deserving of remark is the simple and graceful beauty of the main towers. By giving them the appearance of a solid shaft of steel there is no apparent lack of strength in their lance-like proportions, and there is no such incongruity between the thread-like cables and their supports as exist in the spraddling skeletons of steelwork which were built for the Williamsburg Bridge. As soon as we pass from the general outlines of the structure to its details our satisfaction with the work of the architect and engineer is not so keen. There is a strong feeling of disappointment particularly with the portal view from the Brooklyn end which is illustrated by one of the engravings which we publish. Something of this dissatisfaction can doubtless be attributed to the manner in which the drawing is rendered but there is also a further cause in the method of support of the cables just before they plunge into the anchorage. In the design the saddle piers seem inadequate in comparison with the massive parapet walls. A possible remedy

to this objection without sacrifice of truth might, it would seem, be found in the construction of a portal wall across the bridge at this point. Such a structure, pierced with arched openings and capped with a simple parapet to correspond with the parapet of the main tower seen beyond, would, with the court walls of the anchorage, form an imposing gateway to the great bridge span. It is not, however, our purpose to advance a design for the entrance to the new bridge so much as it is to urge that a further attempt shall be made to improve upon the present design. If this attempt shall succeed in giving the bridge an approach commensurate in beauty with the general outlines, the labor expended will be a bagatelle in comparison with the benefit wrought the city of New York and the art of bridge engineering.

In the proceedings of the Master Car Builders' convention reported in our issue of June 30 there were three items of particular interest. The first of these in importance was the paper by Mr. William Forsyth, M. Am. Soc. M. E., on steel underframe construction for passenger cars. This paper was printed substantially in full in our issue of June 30, and in the same issue we commented especially upon some of the features of the designs presented for consideration. It was one of the surprising features of the convention in some respects that this paper did not receive more extended discussion. That this was so was due probably more to lack of information possessed by the members than to any disregard of the growing importance of steel in the solution of the passenger car problem. In another year we may expect to find that experience has begotten more knowledge and that the special committee, which was appointed to report in detail on the subject of steel passenger cars, will have some valuable information to present for consideration.

Next to the paper on steel passenger cars, the paper deserving most mention was the report of the committee appointed to design cast-iron wheels for 60,000, 80,000 and 100,000-lb. cars. The designs and specifications recommended by the committee were printed in our issue of June 30, together with the main part of the discussion which followed. Entire agreement of the members on the details of so important a question was not to be expected and the discussion which we have published shows clearly that disagreement existed and will probably continue to exist. There can be no two minds, however, upon the value of the work that the committee has done. The mere task of securing an agreement of wheel manufacturers on a common design and specification is an accomplishment to be proud of and this at least the committee succeeded in doing. We think that this feature of the work was hardly given the credit that it deserved, for it was a far more difficult task than that of merely designing a suitable wheel and of specifying its composition and construction. Differences of opinion on the details of these questions can be easily adjusted now that a common basis of co-operation has been developed from which to work.

The third subject which received the attention of the association was the question of air brake hose specifications. For some time the opinion has been growing that the standard specifications of the association demanded a quality of hose which was unnecessarily high and, in fact, which was uneconomical. In a series of tests reported at the June meeting of the American Society for Testing Materials, Mr. Max Wickhorst showed that as good service may be expected from a hose having a low friction and low stretch of rubber, providing the hose is substantially made, as can be secured from the high-class hose formerly specified. In addition, by not specifying a woven hose with seamless tubing and by reducing the friction and stretch requirements, a hose can be secured which is some 30 per cent. cheaper than that formerly required as standard. In further support of the contention that a cheaper grade of hose was desirable figures were presented showing that at least 80 per cent. of hose failure were due to mishandling, poor mounting and other circumstances with which the quality of the hose had nothing to do. The very reasonable argument from these facts was that it did not pay to buy an expensive quality of hose to be smashed about and destroyed when a cheaper hose would satisfy fairly well the few instances in which the enduring qualities of the material were actually called into service.

SHOULD ENGINEERING SCHOOLS BROADEN THEIR COURSES?

President J. G. Schurman, of Cornell University, in his annual report, states that the number of students taking courses in "the college of arts" is falling off, not only in Cornell but in Harvard and Princeton. On the other hand, the number of students taking courses in engineering has steadily and rapidly increased. In comment upon this showing President Schurman says:

> The diminishing rate of increase in the attendance (in Arts courses) seems to be a general phenomenon little influenced by differences in the curriculum (of different colleges). Undoubtedly it is due to the bent of the age toward things practical and utilitarian, the desire of young men to fit themselves as soon as possible for earning a living, the great opportunities for money making offered by the industrial and commercial world, and the too prevalent conception of wealth as the chief good in life. A training in engineering, for example, enables a young man at once to enter into these material possibilities; a course in Arts does not. . . . Although the number of students who elect Greek is not large, a saving remnant still yield themselves captives to the charm of Hellenic humanism and idealism. . . . Greek is still alive in our best minds, and at home in our conception of liberal culture.

Without endorsing President Schurman's defence of Greek as an essential to liberal culture, there is certainly much in his words worth the serious attention of those interested in the work of engineering education.

The tendency toward the scientific and the practical in education which President Schurman remarks is of course no new thing. Two generations ago Herbert Spencer wrote his celebrated essay on education, and sounded the death-knell of "the classics" as an essential element in education. He did not deny that the study of the dead languages may train and develop the mind; but he did question the value of such study in comparison with the study of the sciences. His remarkable foresight is nowhere better shown than in his prediction that men would soon come to see that a better mental training can be had by solving physical problems than by parsing Greek verbs, that as much true pleasure can be taken in a study of nature as in the study of other men's conceptions of nature, that first-hand knowledge is more satisfying to the *best* minds than yielding to the "charm of Hellenic idealism."

No one will question at the present day that the addition of the natural sciences to the old-time arts course has greatly enriched it, and the sciences are now undoubtedly the most important part of a liberal education. What better test can we apply to the liberally educated man than the question whether he finds himself deficient in knowledge, and ignorant of things that tend to his mental uplifting? If we take, for example, the subjects of Greek and Chemistry, can there be any doubt that the man ignorant of the elements of chemistry will find to-day his lack of knowledge a hindrance or a mortification far more often than the man who is ignorant of Greek?

But there is another side to the question which we cannot afford to ignore, and that is that the great object of education is after all not the accumulation of knowledge, but the development of mental power in the individual. In the reaction from the old-time classical studies let us beware of going to the other extreme, and rating too low what have been called the "culture studies."

It is true as President Schurman points out, that the attendance at engineering schools everywhere has grown by leaps and bounds during the past four years. If this growth is to go on, and if the bulk of the students turned out from our institutions of higher education are to pursue the courses of study in engineering, then it is a matter of great moment that their education shall be of a high standard of quality.

President Schurman declares that young men prefer the engineering courses because they desire to fit themselves as quickly as possible to earn a living, and because the bent of the age is toward things practical and utilitarian. In this there is, from our standpoint, no ground for criticism; but if those who fix the courses of study so interpret this demand as to sacrifice studies that broaden and enlarge the mental horizon of the student, such as history and literature, they are, we believe, making a wrong choice, and one which in the long run will be to the disadvantage of the student.

This is perhaps a good time to call attention to this matter, for at present, as is well known, the immediate supply of engineering graduates has outrun the demand, and a large proportion of those who graduate from engineering schools this month find themselves unable to secure positions. In such a situation the man is the better off whose four years of study have been devoted to making a man of himself, in the best sense of the word, rather than he who has spent his time chiefly in the study of some technical art, at which he now finds no opportunity to work.

We shall hear the objection made, however, that the engineering courses are already so crowded that there is no time for the culture studies. If this is really the case, then it is worth serious consideration whether some of the time spent on "practical instruction," so called, might not better be devoted to work in literature—to take the branch that probably most needs attention in our engineering schools.

Of course the schools who pursue such a course will be criticised, as they have been in the past. The "practical man" will express his wonder that four years in an engineering school did not make the student an expert instrument man, a neat and rapid draftsman, a competent expert on steam engines, a practical electrician, an authority on road building, and so on.

Engineers know, however, that while four years in a good engineering school may ground the students thoroughly in the sciences on which engineering is based and give him in addition familiarity with some one branch of engineering practice, a lifetime is too short to make any man an expert in all the varied fields of activity covered by the engineering profession at the present day.

The best that can be done beyond the necessary foundation work, therefore, is to familiarize the student with a few branches of engineering practice; and it may and does often happen that the field of work into which the engineer is thrown is far removed from that in which he specialized while in college.

There may be even such a thing as carrying the foundation studies too far. Within a few days the head of a large engineering school has told us that he found his senior students to be admirably adept in calculus, but wretchedly deficient in their knowledge of the English language and how to use it.

Then, too, there are subjects now forming part of engineering courses which furnish little mental training as they are ordinarily taught. Take, for example, lectures and recitations on Roads and Pavements. What is there in the text-books on this subject that cannot be understood at first reading by a graduate in electrical engineering, let us say, who has never studied the subject at all at school?

A little time should be given in a civil engineering course to this subject, but only enough to familiarize the student with the best sources of information for subsequent self-instruction. We cite this only as an example of the subjects whose study may be abbreviated if such abbreviation is necessary to give time for the culture studies.

LETTERS TO THE EDITOR.

Rock Dust Not Always Injurious to Men.

Sir: My attention has been attracted by your review in your issue of June 16, under the heading "Rock Dust as a Cause of Pulmonary Consumption," of a paper on Miner's Phthisis recently read before the Institution of Mining and Metallurgy in London.

The conclusions arrived at by the authors of this paper are so entirely at variance with my personal experience with stone dust in the asphalt paving industry that it may be of interest to your readers to learn of the latter.

One of the constituents of an asphalt surface mixture is an impalpably fine rock dust. This material is added to the extent of about 10% to the hot sand and very thoroughly agitated with it in a dry condition. The result is

that clouds of dust are given off which envelop all those on the platform where the mixer is situated. The mixer man frequently breathes this atmosphere for eight or ten hours per day, and year in and year out at some plants. Workmen under such environment have been under my observation very closely for the last eight years. In no case has any such effect as that described by Messrs. Haldane and Thomas been observed. The workmen are particularly healthy and withstand the high temperature and the dusty atmosphere with no ill effects whatever.

This experience would seem to throw some doubt upon the conclusions of Messrs. Haldane and Thomas, since the conditions are much more severe than any that they have studied.

Very truly yours,
Clifford Richardson,
Director New York Testing Laboratory.

Long Island City, N. Y., June 24, 1904.

Formula for Estimating the Number of Elevators Required for Tall Buildings.

Sir: In your report of the proceedings of the Mechanical Engineers' convention at Chicago, on page 537 of your issue of June 9, I find that you have mixed my statement of my formula for determining the minimum number of elevators for maintaining a given schedule in a building of any height.

I said:

Divide the height by the speed in feet per minute and multiply the result by a constant (which I place at 330), divided by the desired interval in seconds. This would be

$$\frac{H}{S} \times \frac{330}{\text{Interval}}.$$

Please correct, and oblige. Yours very truly,

G. W. Nistle, M. Am. Soc. M. E.
Secy., Illinois Engineering Co.

Chicago, Ill., June 16, 1904.

Tests of Pile Penetration.

Sir: In reply to Mr. Goodrich's request in issue of May 26: In 1903 I had the following tests made in this city in trestles across ravines.

Number of test	1.	2.	3.	4.
Date, 1903	Oct. 14, 6 p. m.	Oct. 23, 5 p. m.	Oct. 23, 5 p. m.	Nov. 2, 5 p. m.
Depth of pile in ground, ft.	30	23	31	25
Hammer fall, last blow, ft.	20	8	8	6
Penetration, last blow, ins.	3	12	12	14
Date second test	Oct. 15, 7 a. m.	Oct. 24, 1 p. m.	Oct. 24, 1 p. m.	Nov. 3, 8 a. m.
Hours interval	13	20	20	15
Hammer fall, ft.	35	25	25	10
Number of blows = n	20	2	2	18
Penetration for "n" blows	1½ ins.	3⅝ ins.	2¾ ins.	13 ft.
Av. penetrat'n 2d day, ins.	.075	1.8	1⅜	8⅔

No apparent difference in conditions throughout except in degree. Case 4 was in a trestle ½ mile from cases 2 and 3.

Yours truly,
E. K. Coe, Asst. City Engr.

Duluth, Minn., June 15, 1904.

A Moment Diagram for Axle Loads.

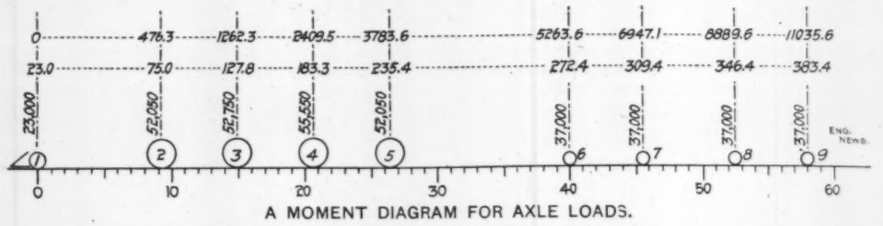
Sir: The accompanying moment diagram for wheel loads may be of interest. The top row represents the summation of moments, in thousand foot-pounds, of all the wheels to the left, including the wheel under the number, about wheel 1. The second row is the summation of weights. The right hand figure is the decimal part. Underneath the wheels is a scale of feet; every fifth foot being numbered. Fractional parts of a foot are estimated by the eye. The zero of the scale is at wheel 1.

The following will illustrate the use of the diagram: The bridge must be drawn to the same scale as the diagram. For simplicity take a simple girder bridge 20 ft. long, the engine coming on the bridge from the right. When wheel 1, say, is 17 ft. from the right end, the moment about this end equals 127.8 × 17 — 1,262.3. Notice that wheel 3 is the first wheel to the left of the right end, and no wheels are off the bridge to the left.

Again, suppose some wheels are off the bridge to the left, say, wheel 2 being 3 ft. to the left of the left end. The scale of feet reads, at the right end of the bridge, 32. The moment about the right end equals 32 × (235.4 — 75) + 476.3 — 3,783.6. Wheel 5 is the first wheel to the left of the right end.

We can now make a general rule for finding moments about the right end of a bridge. Multiply the scale reading at the right end by the weight on the bridge, add the moment of the wheels off the bridge to the left, and subtract the moment of all the wheels up to the right end.

Again, suppose wheel 5 is 14 ft. from the left end. We wish to find the moment of the wheels on the left segment of the bridge about wheel 5. The scale reading at wheel 5 is about 26.3. The moment equals (235.4 — 75) × 26.3 + 476.3 — 3,783.6. Regarding the left segment as the length of the bridge this is exactly like the second illustration above, and with this convention the general rule applies.



A MOMENT DIAGRAM FOR AXLE LOADS.

The following are some of the advantages of this diagram. It can be quickly made and extended for any number of wheels to the right. The writer in calculating old bridges uses the above engine followed by a train of hopper cars having an axle load of 38,000 lbs. In designing by Cooper's loading, the diagram, on account of the simple spacing and loading, becomes very simple. Most of the results can be seen at a glance.

The numbers can be quickly taken from the diagram, since there is no large mass of figures to pick from. The compactness is a marked advantage.

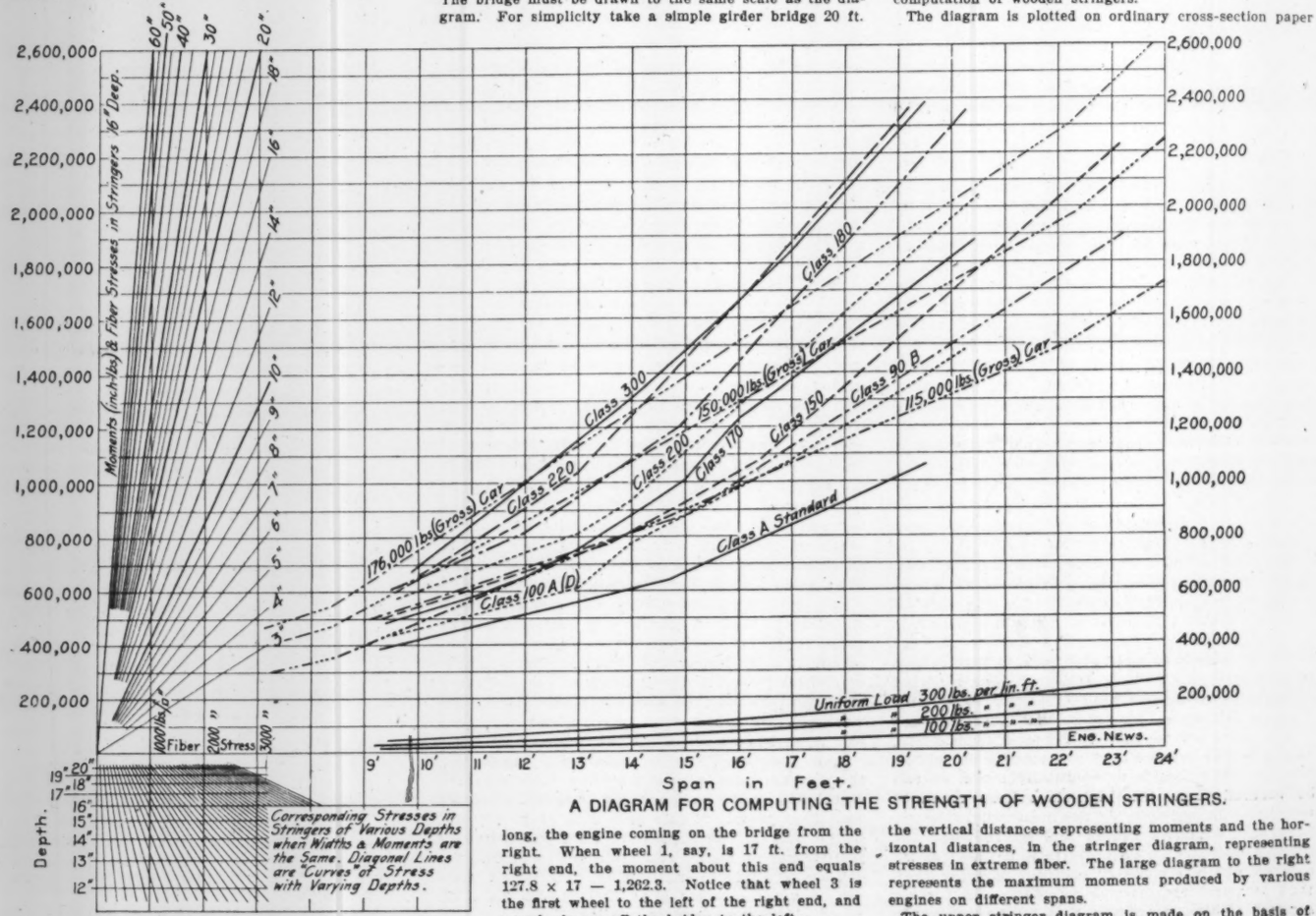
B. R. Leffler,
Bridge Dept., L. S. & M. S. Ry.

17 Olive Place, Cleveland, O., June 1, 1904.

A Diagram for Computing Wooden Stringers.

Sir: I send herewith a diagram devised to facilitate the computation of wooden stringers.

The diagram is plotted on ordinary cross-section paper



A DIAGRAM FOR COMPUTING THE STRENGTH OF WOODEN STRINGERS.

The upper stringer diagram is made on the basis of stringers 16 ins. deep. The radial lines represent stringers of the widths indicated and the co-ordinates of any point on a line are the bending moment and corresponding stress for 16-in. stringers of the indicated width. The construction of this diagram needs no description.

The small diagram below is designed to give stresses on the vertical distances representing moments and the horizontal distances, in the stringer diagram, representing stresses in extreme fiber. The large diagram to the right represents the maximum moments produced by various engines on different spans.

Piles were 10 ins. diameter at small or lower end, blunt pointed, and when driven extended 20 ft. above ground. A steel follower cap was used and a 2,400-lb. hammer, falling free except for trailing rope. The soil is a rather quick sand, with the surface about at the harbor level, in the bottom of clay banked ravines 200 to 400 ft. wide:

stringers of other depths than 16 ins. It is drawn as follows. From a zero line (in this case 1-in. above base of main diagram) point off distances to represent the reciprocals of the squares of various depths. Through each point draw a horizontal line and mark the depth which it represents. Then from the origin in the line of zero draw a system of radial lines.

The use of the diagram may be illustrated as follows: Given a moment of 1,020,000-in. lbs. on two stringers 8 x 18 ins., required, the fiber stress. Two stringers 8 x 18 ins. equal 16 x 18 ins. On the upper diagram the 16-in. wide line intersects the line of 1,020,000 in-lbs. at 1,500 lbs. per sq. in. which would be the stress in a stringer 16 x 16 ins. On the lower diagram find 1,500 lbs. sq. in. on 16 ins. deep line and follow radial line to its intersection with the 18-in. deep line giving the stress of 1,200 lbs. per sq. in. at the stress sought.

Again given moment of 620,000 in.-lbs. allowable stress of 1,100 lbs. per sq. in., depth of stringers 14 ins. required the necessary width. From the lower diagram 14-in. stringers at 1,100 lbs. correspond to 16-in. stringers at 840 lbs.; then from the upper diagram the vertical from 840 lbs. intersects the horizontal from 620,000 in.-lbs., near the radial line giving 18 ins. as the required width.

The use of the diagram is less complicated than the description.

Yours truly,

P. E. Stevens, Assoc. M. Am. Soc. C. E.

497 Carroll St., St. Paul, Minn., May 30, 1904.

Record of a Fire Engine Test.

Sir: Last year the City of Paterson, N.J., purchased two first-size Metropolitan fire engines from what is now the American-La France Fire Engine Co., Elmira, N. Y. Some of the general dimensions of the engines are: Bore of steam cylinders, 9 ins.; bore of pump cylinders, 5½ ins.; length of stroke, 8 ins.; boiler, 36 ins. diameter by 66 ins. high. The makers give the heating surface as 272 sq. ft., and area of grate surface 6.16 sq. ft.

At the request of the Fire Chief, John Stagg, I was present at the acceptance trials in this city, at which these are some of the notes taken:

	Eng. No. 5 a. m. h. m. s.	Eng. No. 1. p. m. h. m. s.
Fire lit, water cold.....	9.35.00	2.42.00
Steam pressure showed on gage..	9.37.30	2.45.15
Pressure, 15 lbs....	9.58.45	2.46.30
" 20 "	9.59.15	2.46.45
" 25 "	9.59.30	2.47.00
" 30 "	10.00.00	2.47.30
" 35 "	10.00.30	2.47.50*
" 40 "	10.00.50	2.50.00
" 45 "	10.01.00	2.50.10
" 50 "	.....	2.50.20
" 55 "	10.03.00*	2.50.28
" 110 "	10.04.00	2.51.25
" 130 " †....	10.04.30	2.51.50

*First fire stream turned on. †Safety valves open at 130 lbs. by gage. Both tests made on May 26, 1903.

After each test was completed, fire was dumped, and with air passing up through boiler and chimney, engine No. 5 with 27 lbs. on gage at 10.00.30 cooled down to 20 lbs. by gage at 10.17, or 7½ minutes for 7 lbs. Engine No. 1, with 47 lbs. at 4.33.30, showed 45 lbs. at 4.35, 40 lbs. at 4.38.30, 34 lbs. at 4.42, 30 lbs. at 4.45.45, and 25 lbs. at 4.49.15 p. m., or 15⅛ minutes for 22 lbs. The first case is equivalent to 1.24 B. T. U., while the second case is equivalent to 1.37 B. T. U. per minute per square foot of total radiating surface. This radiation loss was in part through the outer shell of the boiler, which is left bare in nearly all makes of fire engines as now built; this would add about 55 sq. ft. to heating surface of 272 sq. ft., making 327 sq. ft. of radiating surface. The water level in boiler at close of test was not noted, but no doubt has an influence in connection with the radiation loss. Thirty-three gallons of water are carried to second gage line. These figures may be of interest to some of your readers and may bring out other notes along similar lines, namely, transmission and radiation of heat.

Yours very truly, W. Wallace Christie.

Paterson, N. J., June 29, 1904.

Notes and Queries.

In response to the inquiry in our issue of June 23 for apparatus which will record at a pumping station or elsewhere the height of water in a distant stand-pipe we have received two notes. Mr. Chas. W. Sherman, M. Am. Soc. C. E., of Belmont, Mass., writes that

the Boston and Metropolitan Water-Works have had instruments of this character in use for ten years or more, and have found them very satisfactory. They are made by George E. Winslow, of Waltham, Mass.

Mr. Foster Crowell, M. Am. Soc. C. E., 18 Broadway, New York City, states that he has plans for such a device designed by him for the Redridge dam.

ANNUAL CONVENTION OF THE AMERICAN RAILWAY MASTER MECHANICS ASSOCIATION.

The Railway Master Mechanics Association assembled in convention at Saratoga, N. Y., on June 27 and continued in session for three days. It is a pleasant duty to announce that both in attendance and work done few better conventions of this substantial society of railway officers have ever been assembled. The technical proceedings particularly, were deserving of commendation. Though no particularly striking paper marked the programme, as has often been the case in past years, there have been few meetings where the committee reports and special papers have exhibited such a uniform plane of careful and intelligent work. It is this standard of general excellence that marks most plainly the advance of the Association during recent years in the scientific training and attainment of its members. In support of what has been said, we present the work of the convention as follows:

GENERAL BUSINESS.

The general business of the convention was introduced by an address by the President, W. H. Lewis (Norf. & Wn.), who reviewed the work of the Association during the year, and called attention to the various questions that were to come up for consideration during the convention. The report of the Secretary showed a total membership of 791 and a balance of $2,875 on hand in the treasury after all the bills were paid. The convention voted that the dues for the ensuing year should be $5 per member. These routine proceedings were followed by a motion to adopt the change in the constitution proposed at the convention of 1903. In brief, this change provided for the election of representative members to the Association. In connection with it an amendment was proposed by Mr. H. F. Ball (L. S. and M. S.), providing regulations for controlling the adoption of standard devices or constructions. The proposed change and its amendments were objected to by a number of members who questioned the wisdom or necessity of representative members, and asked that before action was taken an effort should be made to ascertain whether railway companies would appoint such members and abide by the decisions. These objections were not supported by the convention which voted to adopt the changes and amendments as they were proposed. The final business of the convention was the balloting for officers, which resulted in the following elections: President, Peter H. Peck, Master Mechanic, Chicago & Western Indiana R. R.; First Vice-President, H. F. Ball, Superintendent of Motive Power, Lake Shore & Michigan Southern Ry.; Second Vice-President, J. F. Deems, General Superintendent of Motive Power, New York Central & Hudson River R. R.; Third Vice-President, Wm. McIntosh, Superintendent of Motive Power, Central R. R. of New Jersey, and Treasurer, Angus Sinclair.

COMMITTEE REPORTS.

This year, as in the past, the great bulk of the technical work of the convention was the product of special committees appointed by the President of the Association. There were twelve of these special committees scheduled to present reports, and all of these presented either complete or progress reports of work done, which were formally discussed and acted upon by the convention. As listed on the programme, these reports and discussions were scattered through the four sessions and interspersed with individual papers and topical discussions, but they are for convenience sake collected in one place in this account of the meeting. For the most part the discussions were pertinent and concise, but there was in several cases opportunity for the chairman to have clapped the extinguisher on rambling reminiscences and personal biography with gain to the usefulness and dignity of the proceedings. It is to be hoped that the publication committee will remedy this neglect in the final editing for publication.

TON-MILE STATISTICS; CREDIT FOR SWITCH ENGINES.—While it is a simple matter to determine the ton-mileage made by locomotives in general road service it is practically impossible to determine this figure for locomotives in switching service. In the past the practice has been to credit switching engines with a credit of 6 miles per hour, but recent tests have demonstrated that this is about twice the mileage actually accomplished. The old figure of mileage must be abandoned, and to adopt a new figure more nearly agreeing with the facts as determined by test would work an error and an injustice by crediting a 16 x 20-in. and a 20 x 26-in. engine with the same amount of work. To avoid these difficulties it is proposed that the performance of switch engines be determined by multiplying the weight of the engine by the hours worked or on a ton-hour basis. The merits of this measure of work are presented as follows by the committee report:

The ton-hour is not arbitrary, but has a logical and reasonable basis; it is as easily figured as the mileage and will require the keeping of no records not now kept; it is a reasonably accurate measure of the work done and gives a basis from which to determine costs, which is proportional to the work done by the engines because it takes into consideration both their power and the length of time they are at work.

The discussion which followed this report was generally commendatory of the solution arrived at for a very puzzling problem. Mr. Wm. McIntosh (C. R. R. of N. J.) considered that, as there are many road engines used at times in switching service and as these engines do not, like regular switch engines, have all their weight on drivers, it would be more accurate to use the weight on drivers instead of the total weight as the weight factor in calculating ton-hour performance. This opinion was supported by Mr. E. W. Pratt (C. & N. W.) and by Mr. L. R. Johnson (C. P.). Mr. P. H. Peck (C. & W. I.) objected to the recommended ton-hour performance since it would show very unfavorable results on the expense sheets in comparison with previous records. Mr. R. H. Soule suggested that, as road engines have their performance rated on the ton-mile basis while the report recommended rating the performance of switch engines on the ton-hour basis, it would be worth while to search for some factor for converting the engine ton-hour into train ton-miles and have all engine performance on the same basis. He had studied the question somewhat and while not arriving at a result which satisfied him he thought that such a result could be arrived at and the figure would be somewhere in the neighborhood of 200; that is for each ton-hour of engine service there was being performed about 200 ton-miles of train service. The discussion was closed by a motion that the ton-hour basis or rating switch engines be adopted with the substitution of weight on drivers instead of total weight of engine as the weight factor. This motion was carried.

COAL CONSUMPTION OF LOCOMOTIVES.—The committee on this subject divided its report into the following subdivisions: Is the operation of large engines what it should be from a standpoint of engineers and firemen? Are the present tendencies as to large grates and heating surfaces advantageous and are the propositions correct? Is the large locomotive giving results in operation which would be expected from the large increase in capacity? Is the operating department of railways deriving the amount of assistance and relief from large locomotives which may justly be expected, if not, how should the attention of locomotive designers be directed? Each of these questions was considered separately and at some length in the report and a number of tables and diagrams were presented showing results of tests and records of performance. The number and size of these tables and diagrams and the length of the discussion preclude their presentation in full, and as the report will soon be available in the published proceedings of the Association, we give here only the summary of conclusions made by the committee:

The increase in efficiency of enginemen and firemen in road service depends largely on the employment of suitable material to fill the position of firemen.

That for numerous reasons proper consideration has not in the past few years been given to this matter and has led to diminished efficiency in coal consumption, influenced also by the method generally followed of pooling the engines without proper facilities to maintain them in such handling.

That the relatively large boiler results in economy, as indicated in the body of the report, not only in itself but also economy in the engine, so that it is desirable to have as large a boiler as the limitations imposed by the engineering department will warrant for any particular design of locomotive.

That the grate area of the locomotive boiler should be limited to a certain rate of combustion per square foot of grate and that small decrease in efficiency in boilers is obtained by increasing the rate of combustion within a maximum limit of 120 lbs. of coal per square foot of grate per hour, yet due to the fact that with a slow rate of combustion a milder draft will serve from the standpoint of the locomotive actually moving the train (assuming the same efficiency of firing obtains) the large grate with a slow rate of combustion has an advantage in increasing the efficiency of the engines.

That the loss of fuel at delays is probably greater as the area of the grate increases is in a measure offset by the fact that with a large grate a large engine is expected, resulting in operating fewer trains to move a given tonnage and consequently diminishing such delays, which would have a tendency to counterbalance the increased fuel consumption due to increased grate area, leading to the conclusion that there should be a design of grate of sufficient area to give a certain rate of combustion in order to generate the requisite amount of steam to develop a given power which would be a compromise between loss due to delays and at terminals from the large grate and the loss in efficiency while running due to the small grate.

That the introduction of designs of locomotives with a large proportion of the weight on trucks and trailers has resulted in efficient performance as regards fuel economy for both boiler and engines has been illustrated by consideration of the B engine in the report, and generally with this design the capacity of the boiler is relatively increased in proportion to the available power developed by the cylinders (which is limited by the weight on drivers) and consequently such designs would be best adapted to give efficient performance where a relatively high horse power is to be maintained for a comparatively long time such as, for instance, in passenger service or in through freight service.

That the relative worth of a large unit of power to a small unit warrants the maintenance of large engines to a higher standard than small engines and to accomplish this proper facilities should be provided.

That the method of comparison of locomotives in road service from a standpoint of fuel economy should be such as to eliminate as far as possible the influence of variable conditions which might lead to erroneous conclusions from statistics now compiled remembering that the value of fuel consumption should be proportional to the power developed by the locomotive.

The discussion which followed this report was confined almost exclusively to the question of stoking modern large engines and the difficulty of securing and keeping competent stokers or firemen. The pros and cons of the large engine as respected ease of firing and particularly the delinquencies of firemen were feelingly discussed by a score of members, but without arriving at any conclusion other than that competent firemen were difficult to secure and retain. Prof. W. F. M. Goss pointed out that the report indicated that the results obtained, so far as the amount of coal burned for a given amount of work done was concerned, were substantially the same with large grate engines as with small grate engines. This he considered was due to the fact that the saving brought about by the large grate in reduced loss of cinders and sparks through the stack was offset by the greater skill required and not attained in the work of firing.

LOCOMOTIVE FRONT ENDS.—The committee on this subject was appointed in 1903 to continue the series of tests inaugurated by the "American Engineer" and after drawing up a programme of tests estimated to cost $2,150 was compelled to discontinue work because of a decision by the Executive Committee of the Association that it had no authority to grant money for conducting tests except on authorization by direct vote of the Association. In its report the committee outlined the work done and asked that enough money be granted to enable the tests to be carried out. The report being presented the convention on motion of Mr. H. H. Vaughan voted that the executive committee should, as funds became available, appropriate at its discretion such money as the tests called for and not exceeding the sum of $2,150.

LOCOMOTIVE AXLES AND FORGINGS.—This committee was continued from last year to consult with committees of the American Society of Mechanical Engineers and the American Society for Testing Materials with the purpose of bringing about a common standard specification for locomotive axles and forgings. As a result of this consultation the committee reported a modification of the specifications submitted last year by changing the minimum reduction of area to 25% and introducing a bending test. The new specification was submitted as a report of progress and suggested that the subject be held open until after the meeting of the International Railway Congress in Washington in May, 1905. By vote of the convention the committee was continued with power to act at the congress.

BOILER DESIGN.—The committee on this subject presented the replies received by it from railway officials in answer to a letter of inquiry and also presented the details of a series of tests on the temperature of water in various parts of locomotive boilers which were made in 1903 by the Chicago, Burlington & Quincy R. R. The summary of this information by the committee is as follows:

The lowest visible portion of the water glass and the lowest gage cock should be not less than 3 ins. above the highest point of the crown sheet for carved and flat crown sheets. The location of both glass and gage cocks should be as near the vertical center line of the boiler as possible without being out of reach of the engineer. There should be 8 ins. of exposed water glass and three gage cocks set 3 ins. apart vertically. Crown sheets sloped ¾-in. per foot represent very general practice and this slope has proved satisfactory. An automatic low-water detector seems not to be a desirable attachment to locomotive boilers. The form of radial stay that is recommended is shown by Fig. 2.

In order to obtain information as to the temperature inside a boiler as related to leaky flues and burned side sheets, the committee made temperature tests with fusible metal in the water leg, between the flues and inside of flues plugged up. While the tests show temperatures considerably above saturated steam temperatures in most cases, the committee has concluded that the method of determining temperatures by means of fusible metal is not satisfactory and believes that temperatures should be determined by more delicate means, such as the thermopile, and that such determinations should be as numerous as possible in order to trace the direction of circulation in the boiler. On the other hand it is quite possible that the very high temperatures which are probably required to destroy sheets and cause leaky flues are confined to the sheets themselves, and that little if any higher temperatures exist in the water than have already been found by the fusible metal tests.

This point is one which, so far as we know, is not definitely determined, although it has been proven that the temperature of the sheet approaches much more closely that of the water than that of the heated gases. It is essential that the circulation within the boiler shall follow such lines and proceed with such regularity that solid water may overlie all portions of the heating surface.

Since circulation is due to the excess of weight of a comparatively cool column of water over a hotter and lighter body or a mixture of hotter water and steam, the design of boiler which least impedes the flow due to this head will permit of the most rapid circulation, and hence, most rapid carrying away of heat from sheets. It would follow also that the greater the depth of boiler the greater the head to produce circulation at the point where most needed, namely, just above the fire line.

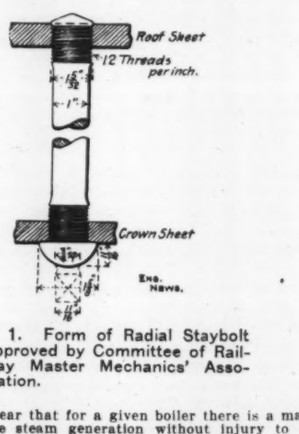


Fig. 1. Form of Radial Staybolt Approved by Committee of Railway Master Mechanics' Association.

It would appear that for a given boiler there is a maximum allowable steam generation without injury to the sheets, determined by a maximum possible circulation in that particular boiler.

Through the courtesy of Mr. F. H. Clark, Superintendent Motive Power, Chicago, Burlington & Quincy Ry., the committee is permitted to present the results of experiments made to determine the temperature of the water in various portions of the boiler when the locomotive is standing, no steam being used from the boiler excepting as required to supply the injector. The results of these experiments indicate that when the feed is delivered in the usual manner to the boiler, the water in the water-leg on the opposite side may have a temperature 100° less than the normal temperature of the boiler, and that the intermixing is greatly improved by using a perforated pipe extending beyond the check within the boiler either longitudinally or transversely, and also, by the omission of a pipe but by means of an orifice which opens upward. In the progress of the tests it was found, also, that when the intermixing was most complete, the drop in steam pressure was greatest, so that it may almost be said that the degree of intermixing in any given boiler may be judged by noting the rapidity with which the steam pressure falls under the action of the injectors when the locomotive is at rest.

In discussion of the report Mr. G. R. Henderson drew attention to the staybolt design illustrated and stated that for oil burning engines a better fastening at the crown sheet was to taper the threaded end of the bolt and dish the underside of the sheet so that the bolt could be headed over into the dishing and would, therefore, project to be burnt off by the fierce oil flame. Mr. H. A. Gillis (Am. Loco. Co.) considered that the fastening described by Mr. Henderson was the best for coal burning engines as well. Mr. A. M. Waitt commented on the lack of agreement regarding the proportions of grate surface, length of tubes, etc., and to remedy this proposed the following resolutions:

Resolved, That the executive committee is hereby authorized and empowered to promote and direct the raising and expenditure of a special fund not exceeding $5,000, to be used under the direction of a special committee for conducting a careful series of experiments and tests concerning the values of varying proportions and dimensions of heating surface, grate surface, and such other important features of boiler design as may in the opinion of the committee, be found desirable.

After some remarks by several members in commendation of the proposed action, the resolution was adopted by vote of the convention.

REVISION OF STANDARDS.—This committee was appointed to revise the present standard on shrinkage allowance for wheel tiers and to revise the specifications for boiler steel, boiler tubes and cast-iron engine truck and tender wheels. It reported in favor of maintaining the present shrinkage allowance of 1-80-in. per foot of diameter for tires for both steel and cast-iron centers. For boiler steel the report recommends the adoption of the present specifications of the American Society for Testing Materials with the exception that for firebox steel a carbon element of from 0.15% to 0.25% is specified. The report recommends the same specification for iron tubes as is now in force except for a slight rearrangement of the various paragraphs. For steel tubes the following specification is recommended:

1. Tubes are to be cold drawn, seamless and made of open hearth steel. It is desired that the steel from which the tubes are manufactured should have the following chemical composition:

	Per cent.
Carbon	.15 to .20
Manganese	.45 to .55
Sulphur, below	.03
Phosphorus, below	.03

Tubes containing more than .03 phosphorus or sulphur will be rejected.

2. Tubes must be of uniform thickness throughout. They must be circular within .02-in. and the mean diameter must be within .015-in. of the size ordered. They must be within .01-in. of the thickness specified and not less than the length ordered, but may exceed this by .125-in. They must be free from bends, kinks and buckles.

3. The minimum weights of the tubes of various diameters and thicknesses are given in the following table:

Outside diameter.	Nominal B. W. G., No.	Thickness M. M. G., Ins.	Minimum weight per foot, Lbs.
1¾-in.	13	.095	1.69
	12	.110	1.92
	11	.125	2.15
	10	.135	2.29
2-in.	13	.095	1.91
	12	.110	2.19
	11	.125	2.47
	10	.135	2.65
2¼-in.	13	.095	2.16
	12	.110	2.48
	11	.125	2.80
	10	.135	3.01
2½-in.	12	.110	2.73
	11	.125	3.04
	10	.135	3.41

4. BENDING TEST.—Strips ½-in. in width by 6 ins. in length, planed lengthwise from tubes after having been heated to a cherry red and quenched in water at 80° F., shall bend in opposite directions at each end, without cracks or flaws.

5. EXPANDING TEST.—Sections of tubes 12 ins. long shall be heated a length of 5 ins. to a bright cherry red in daylight and then placed in a vertical position and a smooth taper steel pin at blue heat will be driven into the end of the tube by light blows of a 10-lb. hammer. Under this test the tube must stretch to 1¼ times its original diameter without splitting or cracking. The pin used shall be of tool steel tapered 1½ ins. to the foot. In making this test care must be taken to see that the end of the tube is smoothly trimmed.

6. CRUSHING TEST.—A section of tube 2½ ins. long, when placed vertically on the anvil of a steam hammer and subjected to a series of light blows, must crush to a height of 1½ ins. without splitting in either direction.

7. FLATTENING TEST.—A test piece of tube 6 ins. long, when flattened lengthwise cold until the sides are separated by a distance equal to the gage of the tube, must not show any splits or cracks.

8. One tube is to be tested as required in paragraphs 4, 5, 6 and 7 in each lot of 250 tubes, or less.

9. Each tube must be subjected by the manufacturer to an internal pressure of 1,000 lbs. to the square inch and must be plainly stenciled, "Seamless Steel Tubes, tested to 1,000 lbs."

In respect to cast iron wheel specifications the report referred to the specifications prepared by the Master Car Builders' committee and recommended that no action be taken until these specifications had been acted upon by the Master Car Builders' Association.

The discussion on this report was confined to the necessary motions for referring it to letter ballot for approval of the proposed specifications.

REVISION OF AIR BRAKE AND SIGNAL INSTRUCTIONS.—The revised list of rules reported by this committee was identical with that reported at the convention of the Master Car Builders' Association and referred to in our issue of June 30. The report was referred to letter ballot for adoption by the Association.

PISTON VALVES.—The specific tasks of this committee were to determine, first, the loss of steam due to worn packing rings; second, whether the steam or the exhaust rings are responsible for the decreased efficiency due to wear; third, the proper lubrication of valves when drifting; fourth, the relative sitting for piston and slide valves, and, fifth, the value of by-pass valves for piston valve engines. The report considered the first and second questions together. Comparative tests

of piston and slide valves were made on the Norfolk & Western R. R., and the Lake Shore & Michigan Southern Ry. The results of these tests are given in detail and are summarized by the committee as follows:

Taking up first the question of leakage, we find that on the Norfolk & Western Ry., a piston valve in good condition loses from 250 to 400 lbs. of steam per hour. The worst valve tested on this road showed a loss of 544.31 lbs. per hour. On the Lake Shore & Michigan Southern Ry. the best result was 540 lbs. per hour, and this on an engine that had mileage of 39,000 miles. Another engine with valves in good condition had a leakage of 858 lbs. per hour, with a mileage of 13,000 miles. The worst case was on the Lake Shore & Michigan Southern Ry. with a leakage of 2,880 lbs. per hour, on an engine with a mileage of 36,000 miles.

Comparing these results with slide valves, we find that the best engine on the Norfolk & Western Ry. showed a leakage of 537.05 lbs. per hour. On another engine the right valve leaked so much that the steam could not be condensed, and the left valve on this engine had a leakage of 740.8 lbs. per hour. The best slide valve on the Lake Shore & Michigan Southern Ry. showed a leakage of 348 lbs. per hour. This valve was in good condition, and had made a mileage of 17,500 miles. Another engine, with a mileage of 39,000 miles, had the valves cut, but were wearing smooth; had a leakage of 2,610 lbs. per hour.

The conclusion derived from these tests do not seem to favor either type of valve. The best piston valve shows a leakage of 268.56 lbs. per hour; and the best slide valve 348 lbs. per hour. The worst case of leakage with piston valves was 2,880 lbs. per hour; and of side valves 2,610 lbs. per hour.

On most roads piston valves are not given the same attention as slide valves, both when fitting up new valves, and care of them when in service. If both kind of valves were given equal attention it is the belief of the committee that the piston valve would be the better as regards leakage around the packing rings.

Questions three and four were not reported upon as the series of tests being made to determine the answers could not be completed in time for publication. The fifth question on the value of by-pass valves for piston valve engines was considered under two heads, as follows: Can a piston valve be operated safely without by-pass valves? If not, what are the elements essential to a satisfactory by-pass valve? The report discusses these two questions as follows:

The need of some kind of relief for the water of condensation in the cylinders or caused by foaming in the boiler, was recognized from the beginning of the application of piston valves to locomotives. The old-time slide or "D" valves were perfectly free to lift from the seat and thus relieve the cylinders of water or undue compression; in this respect the valves were automatic. When the balanced valve was introduced the lift of the valve became limited by the proximity of the balance plate; however, the reduction of pressure upon the top of the valve allowed an earlier relief than with the unbalanced valve, and the decreased lift was compensated by an earlier opening. Piston valves operating in cylindrical bushings, scarcely larger than the valve itself, can not lift, and if no provision was made, any excess of water in the cylinders would probably damage the cylinder, its head or the piston. This is particularly likely to happen with foaming waters. In the western portion of the United States waters containing large quantities of alkali (soda salts) in solution are common, and if the amount of such matter exceeds 40 or 50 grains per gallon priming is almost sure to occur. Other waters may not inherently possess foaming qualities, but when treated, in order to prevent incrustation (as with waters containing sulphate of lime or magnesia) the soluble salts remaining in solution constitute a distinctly foaming characteristic. In such cases it is of great importance that some relief be provided.

The elements essential to a satisfactory by-pass valve may be enumerated as follows:

(1) It must be positive in action.
(2) It should be sufficiently large to permit satisfactory operation at high speeds.
(3) It should be simple in construction and automatic in action.
(4) It should reduce the vacuum to a minimum, thus preventing the suction of cinders into the steam-chest.
(5) It should relieve water and excessive compression in the cylinders, thus preventing breakage and overheating, with its consequential difficulty of lubrication when desirable to drift "hooked up" in order to equalize the wear on eccentrics.
(6) It should exclude cold air from the valve chest and cylinder.
(7) It should reduce the draft on the fire when drifting.
(8) It should be low in cost.

In answer to these requirements the report states that there are a number of valves which nearly or altogether fulfil them and cites the Southern Pacific R. R. valve described in the proceedings of 1903, the device of the American Locomotive Co., and a valve used on the Central R. R. of New Jersey.

The only discussion on this report was confined to the motions necessary for continuing the work on questions three and four.

PAINTING LOCOMOTIVES.—This subject was referred by the Master Mechanics Association to the Master Car and Locomotive Painters' Association with a request that it report upon it at the present convention. The report presented was, therefore, the work of a committee of the sister association named. The substance of the report was contained in the following list of suggestions.

(1) As the passenger locomotives run in connection with passenger equipment cars, they should be treated in the manner of finish in all respects equal to the cars.
(2) Freight locomotives should be painted mainly for durability. From this we would not like to be understood as stating that any kind of painting is good enough for the freight locomotive and no attention paid to surfacing, for we consider a certain amount of filling on the rough parts in the line of economy, because it facilitates the cleaning when locomotives are in service.
(3) Castings and woodwork, on which a good surface is desired, should be made as smooth as possible before the application of paint material.
(4) We discourage the painting of locomotives in roundhouses, and would recommend that whenever possible they be run into the paintshop for the finishing coat of varnish.
(5) For painting new parts we consider the following good practice: First day, sand-blast and apply the priming coat of paint; second day, drying; third day, second coat; fourth day, putty and fill rough places with knifing surfacer; fifth day, first coat of rough stuff; sixth day, second coat of rough stuff; seventh day, guide coat and rub; eighth day, two coats of color; ninth day, stripe and letter; tenth day, varnish with finishing varnish; eleventh day, drying; twelfth day, varnish with finishing varnish.

When absolutely necessary, the above practice can be shortened two days by applying two coats of rough stuff in one day and applying the second coat of varnish on the following day, by eliminating the day allowed for drying.

(6) For repainting locomotives undergoing repairs we submit the following schedule, which can be varied as conditions and circumstances may require: First day, prepare and apply priming coat where necessary; second day, putty and knifing surfacer; third day, color; fourth day, stripe and letter; fifth day, finishing varnish; sixth day, finishing varnish.

On account of the difference in the condition of the paint and varnish on locomotives when they are returned to the shops for repairs, we believe that much should be left to the judgment of the foreman painter as to what operations can be added or omitted in order to expedite the work without detriment to its durability and appearance. These schedules are based on the time required for cab and tank, it being understood that the other parts are being coated by the same method as rapidly as the machinists' work will permit.

(7) We would like to emphasize the importance of having locomotives properly cleaned while they are in service, not only to make them more pleasing to the eye, but in order to obtain the best results from the paint material which has been applied.

(8) In the way of labor-saving appliances and facilities we would recommend: The sand blast; the potash vat; the stationary scaffold; suitable mixing benches; paint stockroom (where conditions warrant it).

On account of our inability to describe quality of work, the difference in facilities of handling parts and the wide variation in labor conditions, it is impossible to give definite data as to cost; we believe, however, that the allowance should be sufficient to secure work equal to that on passenger cars, and the freight locomotive should have a smooth surface in order to facilitate cleaning.

AUTOMATIC STOKERS.—The committee on this subject presented a report of experience with the Day-Kincaid stoker. The following is an abstract of the main points made:

SAVING IN FUEL.—The only comparative test that your committee has been able to make shows that there is a saving of not less than 7% when using the stoker as compared to the work done by a first-class fireman. This, of course, would indicate a considerably greater saving as compared with locomotive firemen, as they are ordinarily found. In the case mentioned, the engine equipped with the stoker was in service over its run 6 hours and 30 minutes, while the engine that it was compared with was only 4 hours and seven minutes going over the same length of division. The saving in coal when using the stoker is no doubt very largely due to the fact that when using the stoker the coal is much more evenly distributed, and the furnace door remains closed all the time.

SMOKE.—When using the stoker the smoke is very much lighter in color, indicating of course, a much more thorough consumption of the gases. The darkest color, when the stoker is used, is not more than brown, while most of the time the emission from the stack shows pure steam.

REDUCING THE WORK OF THE FIREMAN.—When the stoker is used the fireman has to raise the coal from the level of the coal bin of the tender into the hopper of the stoker, a distance of about 30 ins. This is more of a raise than when firing directly into the furnace, but it must be remembered that when the stoker is used the fireman is not required to throw the coal at all. With the coal conveyor in service the labor of raising the coal into the hopper will be entirely dispensed with and the work of the fireman becomes simply that of an expert in charge of an efficient machine.

SAVING IN REPAIRS TO FIREBOX.—There is no doubt but that with the stoker in use very much less trouble with leaky flues will be found on account of maintaining a more even heat in the firebox. The sheets of the firebox will last longer for the same reason. It has been proven that corrugation in fireboxes is due largely to the changes in the temperature in the fireboxes.

REGULAR STEAM PRESSURE.—When using the stoker the steam pressure may be kept absolutely constant. This is due to the regularity with which the coal is placed on the gates, the evenness with which it is placed there, and also the fact that the furnace door not being open the furnace is not cooled by the inrush of air.

SERVICE IN WHICH THE STOKER WILL PROVE MOST VALUABLE.—It is the opinion of your committee that on the ordinary American type of engine there is no necessity whatever for the stoker, as the fireman, of course, has got to be kept there, and the work is not such that an ordindry man can not execute with ease, but with the long firebox type of engine on a long run over a division comparatively free from grades, where the engine is loaded to its maximum capacity all of the time, is where we believe the stoker will be found the most valuable, as a machine will not tire, and consequently, will enable the engine to carry the maximum pressure all of the time, and get the full benefit of the tractive power of the engine over a long continuous trip. This can not be done with the hand-firing method on the type of engine mentioned above where the runs exceed 75 miles in length.

CAPACITY OF THE STOKER.—The present type of stoker will throw about 3,000 lbs. of coal per hour. A modern type of passenger engine with 46 sq. ft. of grate surface and burning 200 lbs. of coal per sq. ft. of grate per hour, will require about 9,200 lbs. of coal per hour. The stoker, as it is built at present, will not accommodate such a firebox, but we see no reason why the speed cannot be increased and the size of the trough so increased that a larger amount of coal will reach the firebox each stroke.

The discussion developed a strong opinion in support of the necessity of automatic stokers with the present use of large locomotives, but few members felt confident that the present stoker met the conditions of locomotive work.

LOCOMOTIVE FRAMES.—This report gave drawings of a score or more of designs for locomotive frames and stated that these designs had upon inquiry been found to meet the approval of the steel casting manufacturers, who had also agreed upon the following specification for material:

Material.	
Acid open-hearth steel	.28 carbon. .05 phosphorus. .05 sulphur. .60 manganese.
Frames will be rejected that show less than 20 or over	.35 carbon. .06 phosphorus. .06 sulphur. .70 manganese.

Tensile strength per sq. in. not less than 55,000 lbs.
Elongation in 2 ins. not less than 15%.
All frames to be annealed.

As a result of its inquiries and investigations the committee reported the following conclusions:

Your committee considers cast steel a better material for locomotive frames than wrought iron.

The tensile strength of the steel, suitable for frames, is about 75,000 lbs. per sq. in., as compared with 53,000 to 54,000 lbs. per sq. in. for the best hammered iron.

The cast steel frame is practically homogeneous; that is to say, there are no welds, and it is of a uniform texture throughout its entire length.

The number of projections required for the reception of brake work, tumbling shafts, rocker pins, etc., seriously complicates the production of modern frames in hammered iron, whereas the reverse is true in the manufacture of cast-steel frames.

Generally speaking, steel is intrinsically superior to wrought iron, and all the difficulties experienced with cast steel are mainly chargeable to either design or method of manufacture and not to the steel per se.

To abandon steel for such reasons is a reflection on our engineering skill and manufacturing abilities. Therefore, we should devote our time and skill to the improvement of the art and thereby approximate more nearly the possible theoretical advantages.

The following points are offered, the observation of which your committee hopes will go a great ways toward mitigating the evil.

(1) Sensible design.
(2) Material cast steel, made to a rational specification, careful foundry manipulation, adequate and suitable annealing.
(3) Provide such form of bracing as will prevent "weaving." By weaving is meant a movement of one side independently of the other, or of the separate parts or joints, with reference to each other locally, as per contra, a movement of the frames as a whole, in unison. The bracing should be so designed that the bending, if any, should be synchronous, as referred to the connected parts.
(4) The clip form of pedestal binder preferred to the thimble and bolt type.
(5) Provision for quickly and adequately draining cylinders. This point is just as important with slide as with piston valves.

Frames with single front rails should be made stronger and means provided to stiffen same back of cylinders or between cylinders and front driver.

The discussion on this report brought out no points of particular interest.

COST OF LOCOMOTIVE REPAIR SHOPS.—This committee, of which Mr. R. H. Soule was chairman, presented a series of itemized figures of cost of various structures entering into locomotive repair shops. It was not discussed.

INDIVIDUAL PAPERS.

The wisdom of the Association in adding to its programme of committee reports a number of individual papers was demonstrated at the first year of its trial. Each subsequent year has seen an improvement in this branch of the Association's work until now much of the most valuable technical matter which it produces is contributed by the individual papers. This year there were six such papers and each of them presented briefly and clearly data and discussion which are important in the work of motive power officials. These papers are grouped for convenience in consideration in the following paragraph:

GRATES FOR BITUMINOUS COAL.—This paper by Mr. J. A. Carney, Master Mechanic, Chicago, Burlington & Quincy R. R. gave several tables of results of tests and of information obtained by circular letters to railway officials. The substance of this information and the views of the author respecting grate design are, however, quite clearly given without the tables in the following excerpts:

GENERAL CONSIDERATIONS.—It has been demonstrated that the cheapest fuel for locomotive use is that which can be bought for the lowest price per ton, and it rests with the railroad mechanical engineer to so design his engine to burn this cheap fuel with the least inconvenience. The ash pan is so closely related to the grate

that it is discussed in this paper in connection with grates.

There are probably as many designs of locomotive grates used as there are grades of coal, and each one has its advantage with certain coals, and some coal is unsatisfactory with any kind of grate. In designing a grate the first object is properly to support the fire; the second, to admit air enough to the fire to make it burn properly; the third, easily and effectually to stir the coals and shake down the ashes, and the fourth to be able to remove quickly the fire at end of run; a fifth and most important feature to be able to clean quickly and easily the fire on the road. With good coal the last feature is not necessary, but there are so many roads forced to use an inferior grade of coal that cleaning fires on freight engines on the road is an important item of time, and there is hardly a road in the Middle West that does not have its share of freight delays due to cleaning fires on the road.

In connection with grates, and of nearly as much importance, is the ash pan. This must be tight at all times to prevent loss of hot ashes, and yet have enough openings to admit air freely to the under side of the grates. It must have sufficient volume to carry ashes made during a trip of many hours, and should dump easily and clean itself with a minimum amount of labor. There should be no flat places where ash can collect and fill up to the grates.

With the large fireboxes and restricted space under them, the design of a satisfactory ash pan is no small undertaking. While the air openings, according to theory, need be very small, they should in practice be as large as possible and allow the passage of sufficient air not only to burn the fire but cool the grates and accumulation of ash on them as much as possible. Theoretically the air openings in the grates should be of just enough area to admit, without undue friction, a quantity of air needed to replace the hot gases drawn from the firebox.

Estimating the temperature of the products of combustion in the firebox at 3,500° F., the volume of the gases passing out of the firebox will be about seven times as great as the air passing through the grates, due to the expansion caused by the high temperature. As all of the gases have to pass through the flues, the openings in the grates and ash pan need be one-seventh of the combined area of the flue openings.

According to the above figures, an engine having 44 sq. ft. of grate area and 792 sq. ins. of flue openings, the total area of grate opening should be 114 sq. ins. with 114 sq. ins. opening in the ash pan.

In per cent, with grate area 100%, this equals:

	Per cent.
Grate area	100
Flue area	12.5
Grate opening	1.8
Ash pan opening	1.8

In practice, openings of the theoretical size are assured.

In connection with grate and ash pan air openings a series of tests were made to determine the vacuum in the ash pan, firebox and front end. These tests were made on one class of narrow firebox and two classes of wide firebox engines.

The vacuum readings show a regular increase with the narrow firebox, but with the two types of wide firebox there is no regularity. This was due to the wind, and it was observed that the readings in the cuts showed much lower than when the wind had a free sweep at the engine.

There should be no vacuum in the ash pan. The tests show as high as .4 ins. in the narrow firebox and practically none in the wide firebox with greatest air opening. There is also a marked increase in vacuum in the front end and firebox in the wide firebox design. These results bear out the statement that as large air openings as is consistent with good design should be given both the grates and the ash pan.

Grates should have as large a per cent of opening as is consistent with the coal used, furnishing as much air in as many places as possible, with the hope that some of it will get through the fire. It is not the grates that clog the draft, but the bed of fire on the grates; consequently the farther we get from the theoretical air opening and within the limit of good design, the better.

GRATES, FINGER AND BOX.—The use of the finger grate is somewhat more common than the box construction. The box construction is used in good-coal districts and while roads report some trouble where the coal is fairly good, others who are using poor coal report an endless amount of trouble. The fingered grate has the advantage of breaking up as well as stirring the fire, while the box grate can only lift and lower the fire, without breaking it up. The only objection to the finger grate is the possibility of burning the ends of the fingers if they are not kept level. This can be entirely overcome by care on the part of the fireman and the shaking mechanism kept in repair. The long-fingered grate is better adapted for poor coal than the short finger. It has a more violent action on the fire, breaks it up better, shakes down ashes faster and gives a larger opening through which the fire can be dumped in the least possible time. Grate fingers less than 5 ins. long do not give as good results with coal which clinkers or which fills up the box as those longer than 5 ins., although the general practice is to run under 4⅞ ins.

DEAD GRATES.—As a general proposition, a dead grate is not advisable, especially in the front end of the firebox where there is most need of a good fire, especially with wide, shallow fireboxes. It is easy to accumulate ashes in the front, and if the fire dies and cold air gets next to the flue sheet, it is difficult to make an engine steam.

DUMP GRATES.—Most roads have special dumping grates, both in the front and in the back end of the firebox, and the idea has a great deal of merit, especially when it is necessary to clean a fire on the road. These grates should be shaking as well as dumping grates.

SHAKING GRATES. AREA.—Grates should be designed so that the entire grate surface may be shaken. If it is desirable to stir up the fire in the middle of the box, why not on the sides and especially the ends? The area shaken by one lever may vary with the quality of the coal, and if the ash melts and cements the grates tight, the shaking feature is out of the question and all designs are equally bad. The grate area shaken by one lever ranges from 7.2 sq. ft. to 29.8 sq. ft. The grates with the last-named area are used with West Virginia coal and practically no shaking is required. Generally speaking, the grate area to be shaken by one lever should not exceed 12 sq. ft. Some recently built engines have the grate lever fulcrum attached to the back of the boiler head with studs. These studs are liable to pull out and it is safer to attach the fulcrum to the deck or tail board.

GRATE SUPPORTS IN WIDE FIREBOXES.—It is impracticable to make grate bars wide enough to extend from one side of a firebox to the other without a central support. This support prevents air from circulating under the fire in the middle line of the box, and there is a dead space a few inches wide from the front to the back of the fire which will clinker badly if great care is not taken in firing.

MATERIAL.—Grates should be made of as cheap a grade of cast iron as can be bought and have the required strength. Hard iron is not an objection, if the cotter and pin holes are carefully cored. Patterns should be accurately made and the foundry required to furnish castings that do not require any machine work. Many roads are following the practice of coring all cotter and pin holes, with excellent results, and a great deal of labor and many small drills are saved thereby.

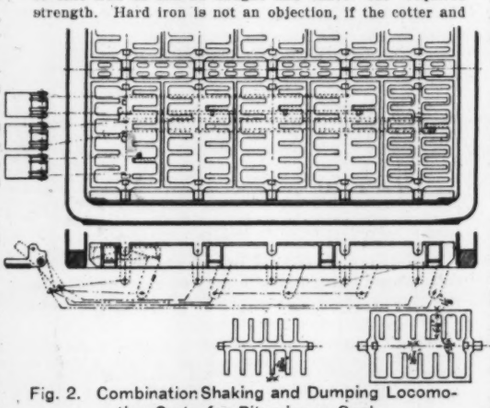


Fig. 2. Combination Shaking and Dumping Locomotive Grate for Bituminous Coal.

PROPOSED GRATE.—A grate should be capable of dumping the front section and the back section independently of each other and the balance of the grate sections, and in addition all sections of the grates should be capable of dumping. Dead grates are not desirable, although they are the practice on many roads. All sections of the grate should be capable of being shaken, and the sections so divided up that not more than 12 sq. ft. of grate surface is shaken by one lever. Grates should be supported by bars on the sides of the firebox only, and these bars should be blocked away from the side sheets at least ½-in. to prevent corrosion of the side sheets. The fingers should be from 6 ins. to 7 ins. long, depending on the length of the firebox and the number of sections into which the grates are divided. The air openings in the grates should be at least 40% of the grate area and 50%, if possible. A drawing of a grate arrangement as outlined is shown in Fig. 1.

PROPOSED ASH PAN.—The ash pan should be self-cleaning and have a free air opening of at least 25% of the grate area, divided equally on the four sides of the pan. No design of pan is suggested, because its form is so dependent upon the frame construction and location of back driving-wheel axle or trailer axle that a satisfactory pan on one engine would be impossible on one of different design. The use of netting over air openings in the pan is objectionable, and so far as possible should be avoided and inclined slats used.

The discussion was opened by Mr. G. R. Henderson who asked the author's reason for objecting to the use of nettings over the ash pan openings. In reply Mr. Carney stated that these nettings obstructed the opening cutting down the free area about 50%. Furthermore, this netting became clogged with dirt and further choked the draft. Mr. Carney also stated that the grate illustrated had been in successful use for 18 months. Mr. John Player (Am. Loco. Co.) considered that the proposal to make the ash pan opening 25% of the grate area would be difficult to accomplish with modern large grates of 80 to 90 sq. ft. area. He thought that the area of ash pan openings should be based on the area of the flue openings. In regard to the proposed grate he thought the central bearing bar would give trouble in the task of keeping it clean, and thought that it might be done away with by making the trunnion pockets in the grate rockers instead of in the bearing bars.

TECHNICAL SCHOOL GRADUATES FOR RAILWAY SERVICE.—The author of this paper, Mr. R. D. Smith, Superintendent of Motive Power, Burlington & Missouri River R. R., pointed out the need of technically educated men in railway service and the very general failure of the special apprenticeship system to obtain them and to keep them when once obtained. Failure in the latter respect appeared to be due to several courses. Many graduates found the business of railroading not to their liking and gave it up after a trial. Another reason was that the wages paid special apprentices were so small as not only to be no inducement but to be insufficient for the men to live on while getting his experience in practical work. Still another reason was that the usual shop training was so general that at its conclusion the man was not competently trained in any special line of work and as a consequence could not fill a specialist's position. To remedy these faults the apprenticeship system should be designed to train specialists. To this end the following courses should be provided:

(1) Car Building and Repairs.—The four years' work could be divided as follows: Six months in the freight car shop on truck and body work; six months in the passenger car shop; four months in the paint shop; four months in the wood mill; four months in the bar blacksmith shop; six months in the car machine shop; four months in the yard; four months in the drawing-room; four months in the testroom, and the last six months at large.

(2) Locomotive Building and Repairs.—The four years' work could be divided as follows: Ten months in the machine shop; six months on the floor; nine months in the boiler shop; nine months in the blacksmith shop; four months in the drawing-room; four months in the testroom, and the last six months at large.

(3) Locomotive Operation.—The four years' work could be divided as follows: Three months in the roundhouse as helper; two months in truck gang; one year as fireman; three months as boiler washer; six months with boilermaker; eight months with machinist; four months in drawing-room; four months in testroom, and six months at large.

The last six months of each course could be devoted to such work as the master mechanic saw fit. For instance, there might be one department in which he intended to place the man at the completion of his course. The last six months could very profitably be spent in that department.

By confining the special apprentice to one of these three lines of work he would doubtless be of more value at the end of his apprenticeship than he is under the present system. He would be a specialist in the particular line of work he has followed. There would not be the hesitancy there is at present about placing him in a position. He would surely be more competent under this system than he is under the present one. It is true he would not have had experience in all the departments, but at the same time he will not be entirely ignorant concerning them. If he has been at all observant he will have a general idea of the work in the other departments. At any rate, he will in all probability have a better idea of the work outside of the departments in which he has worked than will a master mechanic who has risen to his position from a mechanic.

The main feature of the paper, which was the system of training suggested in the above quotation, was scarcely touched upon in the discussion which, however, ranged over the entire confines of personal experience and reminiscence without tangible purpose or conclusion.

OTHER PAPERS.—Besides the papers abstracted there was one on "Terminals for Locomotives," by Mr. R. Quayle; one on "Tool Steel," by W. R. McKeen, Jr., and one on "Tests of Variable Speed Motors," by C. A. Seeley. These papers were of a character that make abstract difficult. They were only briefly discussed.

TOPICAL DISCUSSION.

One entire session of the convention was devoted to the discussion of selected subjects relating to minor details of locomotive operation and not considered in the formal reports and papers. There were altogether eight of these subjects scheduled, and each received some discussion, while several aroused quite as much interest as did any of the special reports and papers. These discussions are given briefly in the order in which they occurred.

GREASE FOR CRANK PINS AND DRIVING BOX BEARINGS.—This subject was presented by Mr. F. F. Gaines, who advocated the use of grease instead of oil for lubricating crank pins and driving box bearings and cited personal suc-

cessful experience with its use. The statement was made that consolidation engines equipped for grease in all rod bearings would make 100 miles on ⅛-lb. of grease. There had been no hot pins and no greater pin wear was found; grease was more cleanly than oil, could not be so easily wasted and was less susceptible of misuse. Following Mr. Gaines at least a dozen members arose to commend the use of grease for both side and main rod and driving wheel bearings. These members gave much the same reasons for their pref-

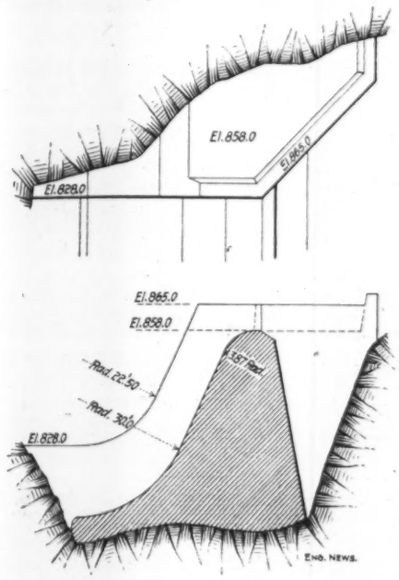


Fig. 1. Plan and Elevation of West Abutment for Dam.

erence as had Mr. Gaines and all stated that there had been a notable reduction of hot bearings with the introduction of grease in place of oil. The most important point brought out was that grease was a failure with babbitted bearings and could be used successfully on solid brasses. One or two instances were cited where babbitt had stood up with grease lubrication, but in most instances the result had been a rapid wearing and breaking down of the babbitt.

CARING FOR LOCOMOTIVE FRONT END EXTERIORS.—Mr. W. O. Thompson opened the discussion of the subject by stating that the best method of keeping front end exteriors neat and clean was to coat it with Walker's smokestack black thinned with Sip's Japan oil; the proportions used were two parts black to one part oil. The cost of labor for application was 12½ cts. per locomotive. Mr. J. F. Walsh (C. & O.) had obtained good results with graphite rubbed in thinly with waste dampened with tallow. Mr. David Brown (D., L. & W.) favored the use of boiled oil well rubbed onto the metal. Mr. F. A. Chase (C., B. & Q.) stated that a thin coat of a mixture of 1 lb. flake graphite, 1 lb. white lead and 1 lb. boiled oil was used by him; a coat would last from five to six days, and cost about 9 cts. per engine.

SCREW LEVER REVERSE MECHANISM.—This subject was presented by Mr. John Player (Am. Loco. Co.) who considered that the substitution of screw reverse mechanism for the usual reversing lever would be objectionable because it would necessarily be more cumbersome and complicated, would cause trouble in emergencies, and would make it difficult for the engineer to know just how much he was hooking his engine up. Mr. David Brown (D., L. & W.) thought that while the present lever was good enough there was not much to be feared from the objections urged against screw mechanism by Mr. Player. In his opinion the objection to both devices was the difficulty of operating them by hand on modern engines and the thing to adopt was some power device for operating the reversing gear. Mr. D. Meadows (Mich. Cent.) considered that no trouble would be had in operating reversing levers by hand if the valves were kept properly lubricated. He considered, in fact, that one of the advantages of the lever was that the ease of its operation showed the engineer the condition of his valve lubrication.

AIR SPACES UNDER LOCOMOTIVE GRATES.—Mr. Francis J. Cole opened the discussion on this subject with the statement that the total net unobstructed openings in the firebox should not be less than 75% of the area of the tube openings. The location of the openings made little difference so long as all the air passed through the grate and the live fire before entering the tubes. Generally he preferred to get as large a proportion of the area as possible by a front opening and to supplement this by back and side openings. Mr. W. T. Johnson (C. P.) considered that the area of firebox opening should be fully equal to the area of the flue openings. A number of members cited instances of engines steaming better when the openings in the ash pan were restricted or practically closed and requested a reason for this peculiar action. In reply Prof. W. F. M. Goss made the following statement:

I think that one view of the ashpan problem might well embrace the whole apparatus which controls the movement of air from the outside atmosphere through the mechanism of the engine and back into the atmospheric air. If you consider that course you will find there is first the front end, taking it in reverse order, then the flues, and then the grate, and then the ashpan. Now, this movement is stimulated by the action of the exhaust jet, and evidently if any one of the elements that I have named is unduly constrained then the exhaust jet will be called upon to do more work than it otherwise would be called upon to do to overcome the constrained condition. So, if the opening in the ashpan is small, evidently we must compensate for that small size of opening by doing a larger amount of work with the exhaust jet, and if we are endeavoring to get the highest efficiency in all parts of the engine, of course we must not have constrained areas where they are avoidable. Evidently the tube area we cannot change materially. That is a factor which is fixed by the general design and proportions of the engine, and we must make our draft act through the tubes at whatever cost. But we do have very great freedom in controlling the opening in the ashpan, and there we should not impose a duty upon the exhaust jet which we can avoid. I was interested in this connection in the facts which were given by Mr. Carney in the paper presented this afternoon. I found that the draft in the ashpan as presented in that paper, representing quite a number of tests, was about 3-10-in., while the total draft was perhaps 3 or 4 ins., and, say, 12% in some cases of the draft effect was consumed in getting the air into the ashpan, whereas if we had no ashpan at all, as was suggested by Mr. Cole, which would be the desirable condition so far as draft action is concerned, we should have saved that 12% of the draft action. Mr. Sinclair called attention to the fact that engines will sometimes steam with the dampers closed. Of course, it is apparent that such an engine either has a considerable reserve of fire to work upon for a time or else it is not working at its full capacity. There are really three ways in which we can check the draft action. We can do it by modifying the exhaust jet; we can do it by modifying the thickness of the fire; we can do it by modifying the area of the opening in the ashpan. I think it is quite true that if engines were always to work at their maximum capacity, our best results would come to us when there were no ashpans, if such a thing were practicable.

RUBBLE CONCRETE DAM FOR THE ATLANTA WATER & ELECTRIC POWER CO.

The advantages of rubble concrete for many kinds of masonry work, and particularly for massive structures like masonry dams, are gradually being recognized by engineers. In many cases where a large yardage of masonry is required the use of rubble concrete will effect a saving in time and cost over rubble masonry work or fine concrete work. As an illustration, rubble concrete composed of 40% large stone and 60% of 1-2.5-5 concrete requires 7% of the volume to be cement, while rubble masonry composed of 65% large stone and 35% of 1-2½ mortar requires 10% of the volume to be of cement. These figures are significant. As an example of rapid construction we present herewith a description of the large rubble concrete dam recently completed for the Atlanta Water and Electric Power Co. at a point on the Chattahoochee River, about 17 miles north of Atlanta, Ga.

The dam referred to is a part of the electric power plant built to supply electric power to the city of Atlanta. A power house at the east end of the dam and a transmission line to Atlanta complete the plant. Briefly described, the dam consists of a west abutment bonding into the rocky side of the gorge; of a rollway section 680 ft. long; of a bulkhead section about 198 ft. long, and of the east abutment connecting with the river bank. The power house is located at the toe of the bulkhead section. In the following description these various structural items are considered separately.

GENERAL PLAN OF DAM.—The site of the power plant is in a gorge of the river, where the rock cliffs are nearly vertical and where the gneiss rock forming the river bed is practically level from cliff to cliff, a distance of about 1,100 ft. The dam extends straight across the gorge and is 1,080 ft. long, including abutments, and 48 ft. high. There are approximately 60,000 cu. yds. of masonry in the structure. The special feature of the design is that the power house bulkhead is made a portion of the dam, as will be described further on.

WEST ABUTMENT.—The west abutment of the dam is a solid mass of masonry of the form shown in plan and elevation by Fig. 1. This masonry is bonded into the side of the cliff and is carried up solid to the level of the crest of the dam. Above this elevation a 7-ft. parapet wall surrounds the abutment, and gives 43 ft. of additional rollway in times of excessive floods.

ROLLWAY SECTION.—The rollway portion of the dam is 680 ft. long, as previously stated, and is built with an unusually heavy section, as is shown by Fig. 2. This illustration gives all dimensions, the stresses and other essential details of the design. To prepare the foundation for the dam the rock of the river bed was cut to a depth of from 5 ft. to 8 ft. along the downstream line of the work. The downstream face of this cut was made nearly vertical and the upstream face was stepped upward toward the heel line so as to come to the natural surface about midway of the cross-section of the dam. As the rock strata had a dip of about 30° downstream, the faces of the cut had a jagged surface that gave an excellent bond to the masonry work.

This masonry consists of a hearting of rubble concrete, with a fine concrete facing and a rubble rear wall. The concrete matrix for the hearting was composed of 1 part Lehigh Portland cement, 2 parts sand pumped from the river bed, and 5 parts local gneiss rock crushed to 2-in. size. The stone used with this matrix were quarried from the local gneiss rock, which was of such character that well-formed pieces were easily obtained. In construction these stone were bedded into the concrete by dropping them a few feet from a derrick and working them with bars. The concrete matrix was mixed very wet, and it was found easy to settle well-formed stone 6 ins. into a 10-in. concrete bed. This fact and the well-formed stone used accounts for the rubble effect of the hearting, as shown by the view Fig. 3. Stones of 4 cu. yds. volume were frequently used,

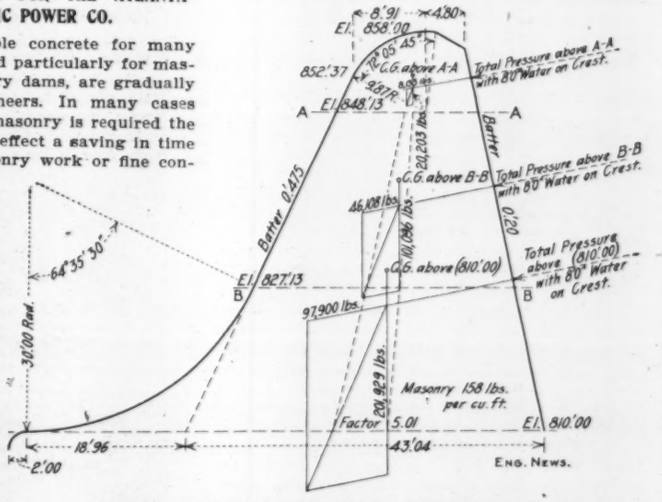


FIG. 2. SECTION OF ROLL-WAY PORTION OF DAM.

and the volume of stone altogether was from 33⅓ to 45% of the total volume of the masonry.

The rear wall of the dam was plain rubble work, consisting of about 40% headers, which extended from 5 ft. to 15 ft. back into the hearting. The

FIG. 3. VIEW OF DAM UNDER CONSTRUCTION, SHOWING CHARACTER OF MASONRY.

object in using this rubble facing for the rear was to secure an impervious surface and to avoid the necessity of concrete forms for the rear face of the dam. The top and the front face of the dam have a 12-in. facing of 1-2-4 concrete. This was built up simultaneously with the hearting, so as to ensure a perfect bond. The view Fig. 3 shows the character of the forms used for placing the front facing. To form the curved top of the dam the hearting was formed roughly to the proper contour and then finished off with concrete by means of templates, as shown by Fig. 4. The curves of the rollway and apron in their more horizontal portions were made smooth by cement mortar applied to the fresh concrete and well troweled. With this exception there was no mortar facing or plastering required, as thorough spading with the 1-2-4 mixture gave an even surface against the forms. These forms were held in place by means of iron rods embedded in the hearting with projecting ends.

For a space of 20 ft. between the rollway section and the power house bulkhead the dam section has been carried up 7 ft. above the rollway portion by producing the back and face batter lines. Through this section two 6-ft. discharge pipes have been placed; these have been provided with head gates and hoists and are designed for relief valves during freshets and to facilitate the placing of flashboards on the rollway, should these latter be used later. A similar discharge tube is placed in the bulkhead, between the exciter units, making three blow-offs in all; the positions of these tubes are shown by Fig. 5, which also shows the general construction of the bulkhead.

BULKHEAD.—The bulkhead and power house design is the familiar type shown by Fig. 6, but with several new devices and appliances. A decided innovation was leaving 16 openings through the base of the bulkhead, having a total area capable of carrying the whole river, even in a moderate flood. This was done to by-pass the river while the balance of the work was built behind cofferdams. The designs provide for the closing of these openings by drop gates at the completion of the work, and later they will be built in solid.

The section of the bulkhead was calculated in detail and given a greater factor of safety than the rollway portion, and these calculations did not take into account any of the power house walls or floor arches, though these add to the stability by acting as a sort of compound buttress. In this part of the construction a much larger percentage of concrete was used, owing to the delay and difficulty consequent to swinging in rubble stones among penstocks, gate guides, etc

EAST ABUTMENT.—The east abutment is formed by three walls that join the power house and bulkhead to the east cliff. Puddle filling is used between the walls, and slope paving is used along the "head-water" sides and surfaces to prevent material from being drawn into the adjacent wheel work.

POWER HOUSE.—The power house or generator room portion of the work is 198 ft. long by 42 ft. wide, and is cut up into eight 24-ft. units. It is supported on 5-ft. concrete walls, the floor being on a system of arches turned between them. This work is joined to the bulkhead work, or rather built with it. Seven of these units are equipped with 48-in. McCormick turbines, one pair to each unit. These turbines are to operate under 48-ft. head at a speed of 187½ revolutions per minute, and will develop 2,400 HP. per pair. They are supplied through 12-ft. penstocks, and are provided with a special crane for purposes of repair, inspection and renewals. The two exciter units are placed in one standard unit space and are equipped with one 21-in. McCormick turbine each.

The seven units are each direct connected with a 1,500-KW. alternating current, three-phase, rotating field generator, of 2,200 volts and 3,000 alternations. The two exciters are direct current 150-KW., 125-volt machines, operating at 450 revolutions per minute.

Seven transformers are located within the generator room. They are 1,500 KW., oil insulated and water cooled. These will transform the output of the generators to 22,000 volts for transmission to Atlanta over a transmission line of about 17 miles.

The superstructure of the power house consists of brick walls, pilastered to carry a 25-ton crane, a system of steel roof trusses and a concrete-steel roof covering. The front or easterly end of the building, for the space occupied by one unit, will be carried up to form a tower or second story to provide space for the high-tension switchboard. The special features of this work are the substitution of a floating caisson, constructed of steel, to take the place of the customary stop-log device in front of the trash racks; the provision of a separate crane for turbine manipulation, and the methods employed in treating expansion cracks in the various structures.

The engineering history of this development started with a report, specifications and sketches by John Bogart, of New York, and Wm. de la Barre, of Minneapolis, acting as consulting engineers for the Atlanta Water & Electric Power Co. The drawings for contract purposes were submitted by the S. Morgan Smith Co., and the detailed designs were made and carried out by

FIG. 4. VIEW SHOWING METHOD OF FINISHING TOP OF DAM.

W. H. Cushman, Chief Engineer. The electrical engineering has been done by the Westinghouse-Church-Kerr Co., of New York.

The contract for the complete plant was let to the S. Morgan Smith Co., of York, Pa., for

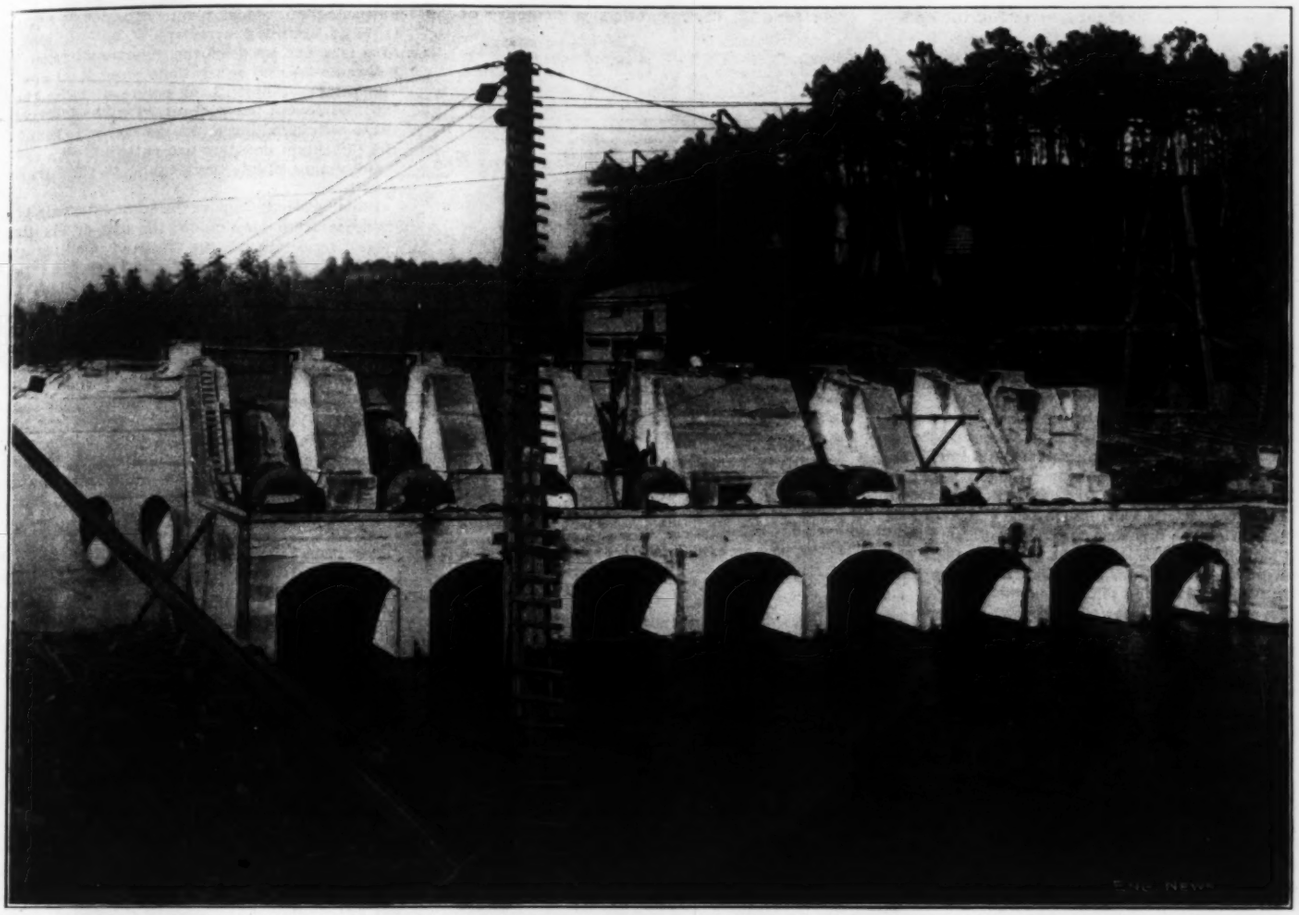


FIG. 5. VIEW SHOWING BULKHEAD PORTION OF DAM.

$1,250,000, approximately. They sublet the electrical equipment to the Westinghouse-Church-Kerr Co., and the masonry and general construction to the Smith-Hardaway Co., reserving the hydraulic machinery and equipment, which they manufactured and provided.

The performance of the contract of the Smith-Hardaway Co. is thought to be a "record breaker" in this style of construction. The first concrete work was started June 1, 1903, and from that time an average of over 5,500 cu. yds. per month was maintained.

The whole work has been built under a most rigid and expert inspection, and by the co-operation of all parties concerned excellent results have been gotten. Mr. Cushman, to whom we are indebted for the foregoing information, is of the opinion that this grade of rubble concrete is ideal masonry for this sort of construction. It produces a monolithic mass free from voids, shrinkages and lines of comparative weakness. Great speed and economy in laying can be effected, and a short calculation will show the relative cost as compared with rubble masonry, viz.: Cyclopean work laid with 40% large stone and 60% concrete (1-2½-5) requires 7% of the volume to be cement. Rubble masonry laid with 65% large stone and 35% mortar (1-2½) requires 10% of the volume to be cement.

SIGHTING BLOCKS FOR TRACK SURFACING AND LINING.

In the maintenance of railway track, the lining and surfacing in detail are largely regulated by the eye of the section foreman, sighting along the head of the rail, sometimes assisted by the use of some form of sighting blocks. The accompanying cuts represent the surfacing and lining blocks invented by Mr. John M. Bailey, of Danville, Ky., and designed to meet the requirements for greater efficiency and economy in work. They are now in use on the Louisville & Nashville Ry., the Southern Ry., and other railways. They are being introduced by the American Track Supply Co., Railway Exchange Building, Chicago.

There are three blocks to a set, each having an upright frame and a cross arm, made of 1-in. No. 12 hoop steel, while each cross-arm has a pair of flags or targets of thin sheet metal. The parts are all enameled, varnished and baked, which treatment is more effective than painting to protect them from scratching or wear. The parts of each block fold together when not in use. Each upright has two legs resting on the rail head and a side piece clamped against the side of the rail by a thumb screw, as shown in Fig. 1. In setting the blocks, a pocket spirit level is used to level each cross-arm. The arrangement of the blocks in use is shown in Fig 2. The "foreman's block" has the flags turned down, and the flags and cross-arm painted black. The "jack block" is similar, but with a graduated arm for use in lining curves, as shown in Fig. 1. The "guide block" has the flags turned upward and is painted white, with a black stripe across the flags; this makes it distinct at a distance, and the black stripe forms the guide line, as shown by the dotted line in Fig. 2.

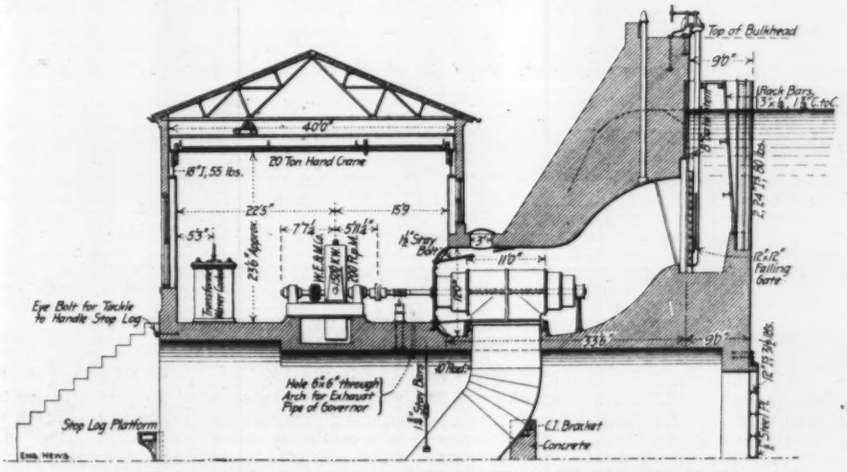


FIG. 6. TYPICAL CROSS-SECTION OF DAM AND POWER HOUSE.

In sighting for surface, the sight is taken over the tops of the cross-arms of the first two blocks to the lower edge of the black stripe on the third block. The jack is set near the middle block and the track raised until this block is in the line of sight. For a long stretch of track, as in a long sag, a number of sights may be taken, the cross-arm of the middle block being raised to bring it into line, and the depression of the rail being noted by the graduations on the vertical bar. The position of the middle block at each sight is marked on the rail and the depression recorded, so that the track can be raised the required amount after the sighting is done.

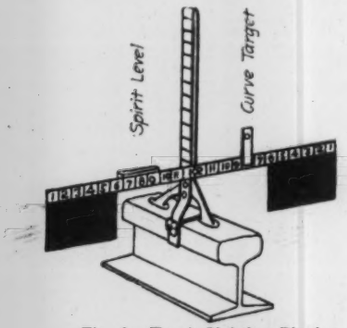


Fig. 1. Track Sighting Block. American Track Supply Co., Chicago, Makers.

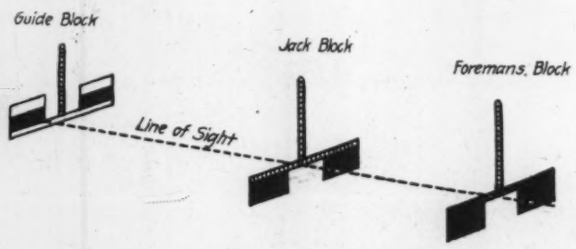


FIG. 2. METHOD OF USING THE TRACK SIGHTING BLOCKS.

In sighting for line, the sight is taken along the outer ends of the flags, the men with lining bars being stationed at the middle, or jack, block. In lining a curve, of known degree, the foreman's block and the guide block are placed 62 ft. apart, and the jack block midway between them; a small red target is then fitted on the graduated cross-arm to mark the middle ordinate of that degree of curve, and this is used for sighting instead of the outer end of the target.

A RECENT FRENCH RAILWAY TIE OF REINFORCED CONCRETE.

The management of the meter gage railway from Voiron to Saint-Bêron in France has had in use in its line since March, 1903, some 60 cross-ties of reinforced concrete, which, according to Le Genie Civil for April 18, 1904, have proved so satisfactory that now about 250 more are being installed to continue the test on a larger scale. An examination of the drawings of Figs. 1 and 2 will make the construction quite clear. Each tie is 1.8 m. (5.9 ft.) long and 18 × 14 cm. (7 × 5½ ins.) in cross-section. The reinforcement consists of three truss-like frames formed by binding a single rod, as shown by the elevation of Fig. 1, and tieing together the top and bottom members. The three truss frames are also tied together across the tie. The reinforcement is so arranged

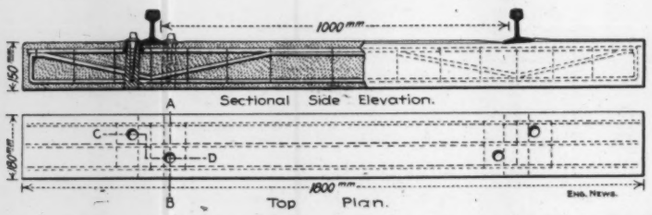


FIG. 1. PLAN AND SECTIONAL ELEVATION OF REINFORCED CONCRETE CROSS-TIE, VOIRON-ST. BERON RY., FRANCE.

that there is a covering of 15 mm. (0.59 in.) of concrete at all points. The reinforcing metal is soft steel.

As will be seen the tie is molded with a depression at each end on top to form the rail seats and two holes are molded in the tie at each end for the rail fastenings. These consist of screw bolts which are driven into wooden plugs set into the molded holes. Wooden tie-plates are set under the rail when it is placed. The weight of the tie is 105 kilograms, or about 231 lbs., and it costs about 90 cts. to manufacture.

PRACTICE ON HIGH-TENSION ELECTRIC TRANSMISSION LINES.

The report of the Committee on High Tension Transmission, presented at the meeting of the American Institute of Electrical Engineers at Chicago, June 22, 1904, contained a summary of the replies received to a circular letter of enquiry. These replies were from 46 plants, as follows:

	Ave. voltage. Volts.	No. of plants.	Ave. length of trans. lines. Miles.	Standard span. Ft.	Max. span with standard const. Ft.
1...	8,000	18	9½	80 to 125	100 to 240
2...	15,000	7	23	80 to 125	100 to 175
3...	22,600	9	32	90 to 140	100 to 300
4...	25,500	4	32	90 to 130	125 to 200
5...	31,300	4	62	100 to 130	360 to 400
6...	51,600	4	75	100 to 180	200 to 320

All these lines are on the three-phase system with the exception of those in the first class, which include 13 three-phase, 4 two-phase and 1 single-phase.

The majority of the plants use cedar poles, and poles are placed 4 to 8 ft. in the ground, according to their length and the character of soil. A few use square and octagonal poles. One has a combination pole consisting of a 7-in. iron pipe 13 ft. long, and an Australian jarra wood top, 7 × 7 ins., 17 ft. long. The life of different kinds of poles are given as follows:

	Years.		Years.
Tamarack	5	Cypress	8
Cedar (Idaho) ...	6 to 7	Chestnut	8 to 16
Cedar (white)	10 to 15	Juniper	15
Cedar (red)	15 to 20		

All but four of the plants have telephone lines on the same poles as the power lines. One plant has the telephone line on poles 200 ft. from the power line. The distance between the telephone and power lines varies from 2 ft. to 8 ft. in the 8,000-volt plants, and 5 ft. to 8 ft. in the 51,600-volt plants; the maximum is 10 ft. 3 ins. In the majority of plants, inspectors attach portable telephones to the line at any point. In one case, stationary telephones are placed in booths two miles apart; and in three cases stationary telephones are placed in boxes on the poles.

Lightning arresters are used by all but one line, which uses barbed wire; four plants use both lightning arresters and ground wire. Barbed wire is generally preferred to smooth wire. Some plants run taps to ground at every pole, some at only every fourth pole, and some at only every half-mile. For mechanical reasons this ground wire is generally run on insulators, but in some cases it is fastened to the pole or cross-arm with staples. Only nine companies consider grounded wires a valuable protection; as a rule they are thought less desirable than other lightning protection. The majority of plants consider that lightning arresters furnish protection against rise of voltage due to any disturbance upon the system, such as the throwing on or off of all or a part of the load. But a number of plants think that for a moderate rise in voltage they furnish no protection. Most plants consider it necessary to have lightning arresters at sub-stations, and arresters are used in the following ways: 1. At power house and substations only; 2, at each end and middle of line; 3, at points dividing the line into four equal parts; 4, at irregular intervals (at cable terminals, etc.). In general it is found that the lightning arresters are satisfactory.

Only eight plants have cables in their transmission lines.

Lines are patrolled at different intervals of time ranging from once a day to five or six times a year, according to the kind of country passed through. Lines running by railway are often patrolled by men on handcars, and lines across country by men on foot and on horseback. The amount of line that a man can patrol in one day varies with the kind of country; in level country ten miles, in hilly country from three to six miles. A man on horseback can do about 30 miles on level or about eight miles in mountainous country.

One company has a lineman and helper to look after 30 miles of line; they patrol line twice a week. Another has three men on a handcar who patrol 30 miles a day. A number of plants do not have their lines patrolled regularly, but only when trouble occurs.

LAYING SUBMERGED PIPE LINES AT BUFFALO, N. Y.

Some interesting pipelaying work has recently been completed across Buffalo Creek, at Buffalo, N. Y., just below the Michigan St. bridge. At this point six lines of 3½-in. steel pipe were laid in the bed of the stream for the carriage of telephone wires; three of the lines are used by the Bell Co., two by the Frontier Telephone Co., and one is for the use of the City of Buffalo.

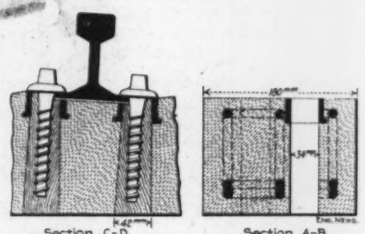


Fig. 2. Details of Rail Fastening and of Reinforcement for Concrete-Steel Tie.

A survey was first made to determine the exact cross-section of the river and the approaches, and to locate the pile-fenders on either side, which had to be avoided. With the data thus secured suitable platforms were constructed, upon which the pipes were to be assembled. These pipes were secured together in straight lengths and then bent to fit the bottom slope by means of a pipe bender. The six bent pipes were next fastened together, side by side, by bolt clamps and telegraph wire lashings. Including asphalt painting and the fastenings, the approximate weight of the six pipes was 60 lbs. per lin. ft. of the structure, or 10 lbs. per ft. each. The length of the pipe line was 230 ft. in a straight line.

Two scows, each about 60 ft. long by 18 ft. wide, were each rigged, on one of the sides, with three breast derricks, and a gin pole was also located at one end of each scow. Ordinary telegraph poles were used in building these derricks, and the guy lines were made of heavy telegraph wire, this portion of the work being done by the employees of the Frontier Telephone Co. These scows were towed along the dock on which the pipe line had been assembled, and the whole line was "hung up" by the derricks and gin poles. A suitable trench had been previously dredged, and accurate soundings were taken at the same time at one-foot intervals near the ends. It was from the data thus secured and laid out on a "natural scale" upon

the adjoining dock that the pipes had been originally bent to conform to the crossing slope.

With the pipe line "hung up" as described, the scows were towed into position across the stream and the pipe was gradually lowered into position. This was done without any mishap. A double 3-in. water pipe line and a line containing telephone wires were laid across the same stream by the Engineer Corps, U. S. A., using much the same method as here described. Mr. G. W. Whittimore is Chief Engineer, and Mr. F. R. Fields is Asst. Engineer of the Bell Co.; and Mr. W. H. Johnston and Mr. W. H. Lamme are respectively Asst. General Manager and Superintendent of Construction of the Frontier Telephone Co., of Buffalo, N. Y.

THE SYNTHESIS OF BESSEMER STEEL.*

By F. J. R. Carulla, F. C. S.†

Nothing is calculated to cause more astonishment to the thinking metallurgist than the success with which the Siemens process of making steel appears to have waged its slow but relentless contest for the mastery over that of Bessemer. For many years the open-hearth process with its deliberate methods seemed destined to permanently keep that place in the manufacture of special steels which was admiringly accorded to it by the makers of the commoner sorts with the converter. Little did they suppose, however, that the rapid operations of the pneumatic process could for cheap material be ever superseded by those of its slower rival. How petrified with amazement such steel-makers must have been if they read the press report of the May meeting of this Institute in 1900 containing the following lines:

BUFFALO CREEK PIPE-CROSSING, BUFFALO, N. Y.—LAID BY THE ENGINEER CORPS, U. S. A.

(This view shows the slinging of the bent pipe-line; and it practically illustrates the method described for laying the heavier pipe-line of the Bell and the Frontier Telephone Cos.)

> It was generally agreed, as put by Sir Lowthian Bell, that the Bessemer process would have to be abandoned, and the open-hearth mode of producing steel substituted for it. Sir Lowthian said, as a member of the Steel Rails Committee, he believed that until they were able to make steel rails by a slower and more manageable process than that of Bessemer they would fail in satisfying present-day requirements.

Could the indictment be more serious, or the condemnation more complete? It is not for the better class of steels that the Bessemer process must be altogether put aside, but actually for rail steel! And this barely two years after the death of Sir Henry Bessemer. Surely the process has something intrinsically worthy of permanence that is independent of the presence of its guiding spirit.

Is this surprising position explainable by the exhaustion in some places of the better class of ores suitable for making Bessemer pig for the acid process, and the consequent necessity to resort to the basic Bessemer more and more? Or, has the condition of affairs complained of been brought about by record-breaking production at a forced pace that makes proper examination of the material before use impossible?

That a grievance does exist is very clear, for Sir Lowthian Bell has expressed an adverse opinion of Bessemer rails on more than one occasion. And yet it is inconceivable that he can bring the acid process under this ban, for so long ago as in 1874 steel rails were being made at the Atlas Works of a quality so uniform as to leave nothing to be desired. That modern requirements could not be equally well fulfilled with the same regularity is a thing that the present writer cannot admit, from the considerations that follow.

*A paper read before the Iron and Steel Institute.

†Derby, England, (Manager, in 1874-76, of the Bessemer Department, John Brown & Co., Ltd., Sheffield).

THE PROCESS.

It is unnecessary to describe the Bessemer process, but it may be useful to have a clear insight of what goes on within the converter, as disclosed by analyses made in 1873, which are shown in Table I.

TABLE I.—Analyses of a Series of Samples showing the changes undergone by Pig Iron during its Conversion by the Bessemer Process.

	Mn.	Graphite.	C. Carbon.	Si.	S.	P.
No. 1. The pig iron as it ran from cupola	....	2.82	0.54	2.399	....	....
No. 2. The same, after blowing 1 minute so as to completely mix..	0.324	2.72	0.64	2.426	0.117	0.044
No. 3. Taken after 11 minutes' blowing.	....	none	2.26	1.285	....	....
No. 4. Taken after 21 minutes' blowing.	....	none	1.14	0.69	....	....
No. 5. Taken at the end, after 28 minutes' blowing.	trace	none	none	0.065	0.127	0.052
No. 6. Steel after adding spiegel...	0.649	none	0.36	0.177	0.119	0.055

It is important to note how rapidly the graphite in the pig iron becomes converted into combined carbon as the blowing proceeds and the temperature rises. No analysis of the spiegel used in the above case is available, but the effect of the high temperature of the decarburised iron or blown metal on the spiegel can be seen from the series of analyses, given in Table II.

TABLE II.—Analyses of Three Heats.

No. of Blow.	Material	Mn.	Graphite.	C. Carbon.	Si.	S.	P.
792	Blown metal	0.36	none	none	0.065	....	....
	Spiegel	13.47	1.22	3.08	1.83	....	....
	Steel	1.04	none	0.30	0.056	....	....
793	Blown metal.	0.058	....	none	0.149	....	....
	Spiegel	19.30	0.46	3.86	1.34	....	....
	Steel	1.08	none	0.29	0.061	....	....
794	Blown metal	0.144	....	trace	0.051	0.064	0.072
	Spiegel	15.60	0.80	3.34	1.77	....	....
	Steel.	0.83	none	0.30	1.117	....	....

The above heats were blown from a mixture of various pig irons in the proportions named in Table III.

TABLE III.—Charge of Heats in Table II.

Brand or Material.	Cwts.	Average Analysis—Mn.	Graphite.	C. Carbon.	Si.	S.	P.
Millom haematite	20	...	3.20	0.76	2.25	0.10	0.02
Askham "	10	0.93	4.50	0.20	3.15	0.08	0.04
Carnforth "	35	...	3.62	0.18	2.55	0.05	0.12
Ditton Brook "	30	...	3.16	0.37	3.04	trace	0.04
Swedish plate*	10	1.987	4.809		0.176	trace	0.122
Metal scrap	10	...	...		...	...	...
Steel scrap	20	...	...		...	...	...
Spiegel	8	...	...		...	...	...

*The author regrets he has no analysis of the Swedish pig or plate used, so that given by Percy in his "Iron and Steel," p. 736, is included in the table for comparison.

It will be seen in Table II. that in every case the spiegel contained a certain proportion of graphite, whilst invariably the finished steel only contained carbon in the combined form.

The importance of this fact will shortly be noticed.

THE SPIEGELEISEN AND FERRO-MANGANESE.—Spiegeleisen originally came from the Continent, and generally contained a low percentage of manganese—from about 5 to 10%. The manufacture of this material had not long been started in England when the author began his Bessemer practice, and it gradually became the tendency to go on increasing its manganese contents, the demand settling down to anything from 20 to 25%. The consequence was that experience was gained with spiegel of very varying percentages.

Occasionally there would be the disposition to use a spiegel with little manganese as pig iron, but this was checked by the knowledge that to put unnecessary manganese into the cupola was unwise owing to its action on the lining.*

Every inducement existed therefore to work up the spiegel in its proper place at the end of the process, and that this could be done without detriment, notwithstanding its occasionally contained graphite, the analyses in Table II. plainly show.

Table IV. gives analyses of Continental spiegels such as had been in use before the material was made in England. The fact that such spiegel had been used with perfect success notwithstanding its contents of graphite soon caused one to have the fullest confidence in the English product. Even when this contained as much graphite as the Continental, the proportion in relation to the manganese was generally smaller.†

TABLE IV.—Continental Spiegeleisen.

Mark	M.	S.	S_1.
Mn	4.60	5.86	6.44
Graphite	0.45	0.40	0.70
C. Carbon	4.10	4.10	3.90
Si	1.23	0.96	0.14
S.	0.16	0.26	0.07
P.	0.12	0.03	0.04

THE CARBON.—Thirty years have not altered the chief characteristic of steel, for that indefatigable investigator, R. A. Hadfield, has recently written:

> But, singular as it may seem, notwithstanding the important part played by all these new iron alloys, carbon still maintains its premier position in determining the practical value of the various products; in other words, there are few, if any, iron alloys in which, apart from the effect produced by the special element added, the presence of carbon is also unnecessary, therefore whatever the theory believed in by each reader of this article, that is, whether he is a carbonist or allotropist, it has to be admitted that carbon alone is the predominant factor in determining the utility of the alloy.‡

Holding this very view in regard to the carbon, it was little wonder that the author took up his work imbued with the great importance of this element, and that to obtain the exact percentage needed in a steel as shown by analysis became his chief aim. The modern Bessemer manager would appear to have still greater reason for thus acting after Mr. Guillet's determination of the numerical value of the equivalent of the principal modifiers of iron which lower by the same amount the points of transformation upon the scale of temperatures. The figures quoted by Hadfield are 1.65 parts of hardening carbon as equivalent to 12 parts of manganese and to 29 of nickel.§ This is very nearly the generally accepted ratio of 1 carbon to 7 manganese, so that, for example, a deficiency in the steel of 0.5% Mn would be more than made up by 0.1% of carbon.

The following was the plan adopted to introduce the requisite amount of carbon into the blown metal to make it into the right kind of steel.

An easy calculation will show that if

x = cwts. of spiegeleisen required;
C = per cent. of carbon in spiegeleisen;
B = cwts. of blown metal; and
n = percent of carbon desired in the steel,

then

$$x = \frac{n\,B}{C - N}.$$

Hence for the 10-ton converters yielding a charge of blown metal weighing 190 cwts., the formula when desiring to produce steel with 0.30 of carbon was

$$x = \frac{27}{C - 0.3},$$

and a handy table was calculated (Table V.) from which one could see at a glance the weight required for each percentage of carbon contained in the spiegel.

TABLE V.—Showing Cwts. of Spiegel Required to Produce Steel with 0.30 Carbon in a Charge of Blown Metal of 190 Cwts.

Total carbon in spiegel.	Cwts. required.	Total carbon in spiegel.	Cwts. required.
5.0%	12.12	4.0%	15.4
4.75%	12.8	3.75%	16.5
4.5%	13.5	3.5%	17.8
4.25%	14.4	3.25%	18.6

*A cupola slag analyzed in 1873 gave—

Silica	40.0%
Hence silicon	18.67%
Oxide of manganese	38.50%
Hence manganese	29.83%

†The excellence of the material made with low-grade spiegel may be inferred from the fact that in 1885 the author learned when at Chicago that the Chicago & Alton R. R. treasured for making frogs some old rails supplied by John Brown & Co. many years before. He found similar appreciation of John Brown & Co.'s rails at the St. Paul, Minneapolis & Manitoba R. R.

‡"The Iron and Steel Metallurgist and Metallographist," January, 1904, p. 20.

§Ibid., p. 18.

This table being for 10-ton converters is of easy modification for those of any other size.

It can be imagined that it was not an easy matter to always dispose satisfactorily, even with the aid of the above table, of such varied materials as those that have been described. One sometimes envied the managers of those rival establishments who obtained something like uniform spiegel or ferro-manganese. Nevertheless, by means of great attention to the bending and the carbon tests, one of which was taken for every blow made, success was achieved. When, however, these got mixed through wrong marking and failed to represent the true heats, steel might go forward not quite suitable for the purpose intended. The necessity for such constant and accurate watch is easily understood when it is considered that a charge from the cupola might be tapped before being completely melted, that the weight of the spiegel might also be deficient, etc. No men were, however, more amenable to instructions than those in charge of the various sub-departments, and the author soon was able to only have to look to his own deficiencies for any failure.

THE MANGANESE.—Now on coming to grips with the synthesis of Bessemer steel the author certainly felt the need of some "key" to the situation that the management of the carbon did not give.

Of course, every one connected with the Bessemer manufacture was aware of the controversy between Bessemer and Mushet, and the important part played by the manganese of the spiegel in the deoxidation of the blown metal. Sir H. Bessemer has himself told how he bought back his first licenses for £31,500, which one can see was clearly because of the inability of those who took them up to work the process in its original form.

Without the modification due to R. F. Mushet's ingenuity, namely, the use of spiegeleisen to recarburise, the process was a failure, but the action of the manganese contained in the spiegel was regarded simply as that of a scourer. The aim of the Bessemer steelmakers seemed to be to employ as little as might be of the manganese for the removal of oxygen whilst leaving in the steel all the necessary carbon.

That the manganese did something more than merely clear the steel of oxygen impressed itself on the author's mind, when on one occasion very good steel was being turned out from one set of converters whilst that from another set was only passable. The mixtures of pig used are given in Table VI., together with the manganese and combined carbon found in the steel.

TABLE VI.—Composition of Charges used in the Manufacture of Good and of Passable Steel.

Hæmatite pig-iron brand.	Steel—Very good— Cwts.	Per cent. used.	Steel—Passable— Cwts.	Per cent. used.
Local	10	7.7	30	15.8
Barrow, No. 3	30	23.1	30	15.8
West Cumberland	50	38.5	60	31.6
Moss Bay	..	....	20	10.6
Cleator	10	7.7	20	10.6
Swedish	20	15.4	20	10.6
Mould Scrap	10	7.7	10	5.3
		100.1		100.3
Mn in the steel		1.17%		0.98%
C. Carbon in the steel		0.33%		0.29%

The most natural deduction to make from the above figures was that the local pig was at the bottom of the mystery, and a thoroughly representative sample was analyzed, with the following results:—

Combined carbon	0.23 } 3.88	per cent.
Graphite	3.68 }	
Silicon	3.69	"
Sulphur	0.158	"
Phosphorus	trace	"

The presence of 0.158 of sulphur was quite insufficient to explain the marked difference between the two steels. Hæmatites were frequently found to contain as much, and even larger quantities; for instance:—

Askham No. 3 had contained	0.123 of S.
West Cumberland No. 3 had contained	0.235 "
And even Millom No. 1 had contained	0.135 "

These had constantly been used in mixtures without detriment, so that one could not look upon this as the solution.

The matter was looked at from various other standpoints, such as the greater purity of the Swedish pig iron, the absence of Moss Bay from one of the mixtures, etc., but they were none sufficient to carry conviction as to any of them being the true cause of the mystery. What one, however, may term the "residual" difference remained—namely, the larger amount of manganese present in the very good steel. It was forced upon one that the much better quality of the one steel was due to the slightly greater quantity of manganese that it contained over the other.

The author's experience had been leading up to this, for he had already found that by proper manipulation of the manganese sound ingots free from honeycombs could be obtained. As direct rolling was being introduced, this was a most important matter. By using the exact quantity of spiegel to introduce 1.35% of manganese into the charge, the object was most successfully accomplished.

To satisfy not only the rail-mill manager but also the tire-mill manager, and the forge manager who had to use it for axles, every one of them pronouncing it "the best steel ever made," was enough to make one think that the "key" had at last been found.

And yet some eminent metallurgists have been unable to believe this. The most venerated in this connection, viz., R. F. Mushet, in a private letter to the Author, in April, 1884, wrote:

But, and here I expect we shall have to agree to differ, manganese in alloy with steel never did, never can, improve it as steel, and this I shall endeavor to prove when I try in Iron to clear away some cobwebs, re Heath's process and mine.

Not so does H. M. Howe express himself in that monumental work, "The Metallurgy of Steel." He says that in 1872 four distinguished steel metallurgists gave him the figures 0.5, 0.5, 0.75, and 1% respectively as the highest amount of manganese which should be tolerated in Bessemer rail steel under any conditions whatsoever, but finds that "to-day" (1891) rail steel occasionally contains as much as 2.1% of manganese, and frequently as much as 1.55%.*

Now, it is perfectly certain that whilst the proper employment of the manganese, as the author found, is the key to the Bessemer process still the percentage to be used will depend largely on the composition of the mixtures employed, i. e., on the chemical composition of the charge, No. 2, Table I., gives a fair idea of what the mixtures were that he employed. They would not greatly vary from this in a twelvemonth, for although the brands of iron used kept changing, so many were put into the mixture that it would be necessary to have had some very bad brand to materially affect the composition.

RAIL STEEL.—And the question here suggests itself, Are the irregularities of modern Bessemer rails due to direct working from the blast furnace? It certainly would seem impossible to obtain so regular a product as in the old way, although a 325-ton mixer should do something towards overcoming the difficulty.

But to return to the manganese. With the mixtures usually employed, analyses of which have been given, it was found that for rail steel so much spiegel should be used as for the manganese to equal 1.35% of the resulting steel, whatever might be the manganese that remained in the steel. It will be well for clearness to call this figure the synthetical manganese, as the whole of this amount would, of course, not be left in the finished steel, which on analysis might not show more than 1%.

A table was prepared for the manganese in the same manner as explained for the carbon (see Table V.), and by working with it, steel giving much more uniform mechanical tests than had been the case before resulted. This was so notwithstanding that the carbon tests might show considerable differences, certainly a result that was as surprising as it was welcome; for working within limits, and not straining the law too far, it was the easiest thing in the world to regulate the manufacture, in spite of the great number of strengths of spiegeleisen that had to be used.

Hadfield has said: "In metallurgical research conflicting reports, unfortunately, often occur on experiments apparently of the same nature; hence the importance of giving, in such work, as full details as possible."† It is regrettable, therefore, that on this point memory alone has to be trusted, and that a series of tests cannot be given. The uniform character of the deflection and of the shape of the broken piece that came away from the test-pieces of rail at the drop are, however, well-remembered facts. The tests were probably not as severe as those imposed at the present day, but neither would the sections be as heavy.

STEEL FOR AXLES.—Except that a considerable proportion of Swedish pig was used in the mixture, the synthetical manganese necessary for axles was practically as when making rail steel, viz., 1.35%.

The Landore Company, however, was introducing its "Siemens" steel for this purpose, and some of the railway companies made their tests more severe. For instance, the requirements of the Midland Railway Co. became that the test axles "must be capable of standing, without fracture, five blows from a weight of 2,000 lbs. falling from a height of 20 ft. upon the axle, which shall be placed upon bearings 3 ft. 6 ins. apart, and turned after each blow."‡

The axle weighed 430 lbs.

For this purpose the synthetical manganese had to be reduced, and just over 1% was found to produce the required steel which contained carbon in the neighborhood of 0.25.

STEEL FOR TIRES.—Swedish pig iron generally formed part of the mixture for making tire steel. The synthetical manganese was 1.25 per cent., as a rule.

SPRING STEEL.—This was the kind of steel where the presence of carbon above a certain limit became an obvious necessity. No amount of manganese made up for the want of carbon where the finished product had to be hardened and tempered. Still there was no difficulty by the choice of suitable spiegeleisen containing from 15 to 17% of manganese and about 5% of carbon to introduce sufficient carbon into the steel to give perfect satisfaction for the manufacture of laminated springs. To get 0.45% of combined carbon in the steel was generally one's aim.

CONICAL SPRINGS.—It was, however, the manufacture of steel for coiled springs of numerous designs that tried the mettle of the Bessemer manager, as no other occupation could possibly have done. Every one is now familiar with the conical spring that John Brown patented.

Every spring, after manufacture, and before it left the works, was tested by dropping a heavy weight upon it from a considerable height, so that the spring was momentarily flattened by the blow into a plain spiral. The spring, if good, resumed its original shape and sent the weight flying up into the air, which falling again upon the spring the action was repeated. This went on a few times with diminishing force and increasing rapidity until the heavy weight came to a standstill. If the steel from which the spring was made was all right, it underwent the ordeal without any damage. If the steel was too soft, the springs became more or less flattened and had to be rejected just as when they broke through the steel being hard. In the technical language of the craft, the springs that became more or less flattened were called "low."

With the success attained in the manufacture of Bessemer steel for the varied requirements of rails, tires, axles, plates, and forgings, it would seem an easy matter to obtain analysis of good and bad springs and go ahead successfully by imitating the good ones. This, however, is easier said than done. There is no doubt that analysis is indispensable in most modern manufactures; but there are, nevertheless, many points in the synthesis of production that it is very difficult, if not impossible, to discover by analysis.

At the same time, analysis is the only possible starting point in any difficulty, and all the assistance that this method of procedure could give was sought. Table VI. will show this:

TABLE VI.—Analysis of Spring Steels.

Steel.	Mn.	Graphite.	C. Carbon.	Si.	S.	P.
Good conical	0.896	0.05 (?)	0.39	0.201	0.083	0.134
do 2d estimation	0.872	....	0.38	....	.....	0.139
Brittle conical	1.168	0.05	0.54	0.089	0.334	0.165
do 2d estimation	....	....	0.54	....	.....	.....

The fact that the good conical contained nearly 2½ times the amount of silicon that the bad or brittle one did is certainly remarkable. As, however, for conical springs the ingots have to be of the soundest character, it is a circumstance that should cause no surprise, knowing the ratio established by Brinell between silicon and manganese, viz., 1 to 5.2, or that "there is 5.2 times more manganese required than silicon in order to obtain ingots of equal density."

There seems to have been some doubt as to the presence of any graphite in the good steel, but after what has been said on the point, the presence of this form of carbon, even in the brittle steel, seems anomalous. In any case, from the larger amount of manganese and combined carbon present in the brittle steel, too much spiegeleisen would seem to have been used in its manufacture. The nearly quadruple quantity of sulphur in the brittle steel must have also greatly influenced its character.

It was natural that in the manufacture of such special steel the attempt should be made to get the most perfect mixing. This was done by turning up the converter after the addition of spiegel and blowing through for a moment. Sometimes this after-blowing would be continued for four seconds. But it was found to be a fallacy to suppose that any stirring of the molten steel is necessary to give it homogeneity. The cause of this is easily explained, viz., that when a heat has to be turned up more synthetical manganese must be used, and of course the after-blow may do one of three things: (1) It may just take out the extra quantity added; (2) it may not do so, leaving an excess; or (3) it may take out too much. If an excess be left, the steel is hard and brittle; if too much is taken out the steel is soft, and the springs made from it are "low."

The important point to note, however, is that this very special steel could be made of an absolutely perfect quality without stirring, proving the needless character of this complication of the process in every other instance. It was also found that mixtures of English hæmatites without any admixture of Swedish were of perfect quality for the special purpose of making conicals. The manganese used had to be well in the neighborhood of 1.25%, while the combined carbon found in the steel had to reach 0.40 or so, and not rise much above 0.45.

CONCLUSION.

No one will be surprised to learn that the Bessemer converter has been discarded for conical spring steel, which is now made in the Siemens furnace. But the circumstance that already in 1874 it was possible to manufacture so delicate a material by the pneumatic process with the success that was at last achieved, plainly shows that the manufacture of rails with perfect regularity was

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* "The Metallurgy of Steel," second edition, p. 46.

†Institute of Civil Engineers' Proceedings, 1888; paper on "Manganese Steel," p. 8.

‡It may be worthy of note that some discussion arose on one occasion as to the equivalent of 1 ton falling through 17 ft. 10½ ins. with 2,000 lbs. falling over 20 ft. A rail was cut into three pieces, and tested on bearings 3 ft. apart, with results as follows:—

(1) 10 cwt. falling 30 ft., first blow, deflection, 4¼ ins.
(2) 20 " " 15 " " " 4½ "
(3) 20 cwt. falling 7 ft. 6 ins., first blow, deflection ..... 2½ ins. } 4½ ins.
20 cwt. falling 7 ft. 6 ins., second blow, deflection ..... 2 ins. }

which practically proved the equivalence of the two tests referred to for 2,240 lbs. x 17 ft. 10½ ins. = 2,000 x 20 ft. These tests also proved the homogeneity of the rail.

mere child's-play. It is inconceivable that the Bessemer converter should not to-day, or even with the added complications of the basic form, be also able to supply uniform material, what ever modern requirements may be, if only the proper procedure is understood.

It is indeed to be hoped that a process that has done such great service in the progress of railway communication throughout the world, and hence in the cause of civilization, which, like the railway system itself, owes its existence to Englishmen, will be capable of restoration in the country of its birth to that confidence that it once possessed, and that it well deserves. Worthy successors to George and Robert Stephenson, and helpers in carrying on their legacy of work, are such names as Bessemer and Mushet, followed by Snelus, Thomas, Gilchrist, and Cooper, who made the basic process possible—all English names; and even Holley, to whose ingenuity the marvelous records of which we read are due, was a citizen of that great English-speaking country that once formed part of this empire, and which our president has done so much to win back, if not to political union, yet in that bond of amity that makes for peace and progress, in the results of which every other nation shares.

LONG SPANS FOR ELECTRIC TRANSMISSION LINES.*

By F. O. Blackwell.†

Many cities to-day are dependent for their lighting, transportation, water supply and the operation of their industries upon electric power transmitted over considerable distances. Unfortunately interruptions of the power service occur not infrequently, and when they do happen they so inconvenience the public as to be most conspicuous. The impression that long-distance power transmissions are unreliable has some basis of fact that seriously interferes with their development. Although absolutely continuous service may not be possible, many of the troubles now experienced can be either altogether eliminated or greatly reduced. Among the principal causes of interruption, so far as the line is concerned, may be mentioned:

(1) Short circuiting of lines by branches of trees, wires, or by large birds getting across them. (2) Burning of wooden pins, cross-arms, and pole-tops by leakage or electrostatic discharges from the conductors. (3) Burning of wooden poles at the ground from forest or prairie fires. (4) Failure of insulators from puncture by the current, or their destruction by missiles, discharged maliciously. (5) Lightning damaging the apparatus connected to the circuits and sometimes destroying poles. (6) Accidents due to heavy winds overturning the poles or to floods washing them out.

The deterioration of a line requires its replacement in from five to twenty years, depending on climatic conditions and the material which is used in its construction. This replacement of the poles with new ones can only be done by shutting off the current or at the risk of accidental interruptions. Let us see what can be gained by substituting a steel tower construction with long spans for a wooden pole line. Short circuits are by far the most common difficulty, the only remedy for which is to put the wires so far apart that they are unlikely to be bridged across. This can readily be done even with more than one circuit when a steel cross-arm is employed. Burning is, of course, entirely done away with where metal construction is used.

Failure of insulators from electrical causes can be obviated by getting larger and better insulators; this is practicable where the spans are long and the number of insulators is small. Insulators on high towers are much poorer targets than when they are near the ground, and so are less liable to be broken.

Each metal tower is a lightning arrester, and as they are the highest points in the line, they materially assist in its discharge; and the tower itself, being a conductor, cannot be injured by lightning. Steel structures can be exactly figured to meet safely any strains that can come upon them and can generally be located at safe places where there is no danger of washouts.

The deterioration of a properly constructed and well-galvanized steel tower is very slight, as is proved by marine and windmill experience, and is practically negligible so far as the pins and cross-arms are concerned. Any part of a steel tower can be readily removed and replaced without interrupting the service.

By far the greatest gain obtained from long spans is in the reduction of the number of parts. If one insulating support takes the place of four or five, line troubles will be reduced nearly in direct proportion, the inspection and repair of the line will be much simplified and its cost of maintenance correspondingly diminished.

COST OF TOWERS.

The cost of a tower construction as compared with wooden poles depends on the locality. Where the right kind of timber exists, it is of course cheaper; but in tropical countries where wooden poles would have to be transported long distances, the towers are much less expensive. In addition, to obtain long life a creosoted wood only could be employed, and this still further increases the expense. The fewer insulators and pins and the ease of transportation and erection are in favor of towers. They can be packed in light bundles suitable for mule-back transportation, and quickly put together even in the most inaccessible places. Even where the cost of the tower construction is more it is often justified by the greater certainty of operation which it insures and the lower cost of maintenance.

STRENGTH OF CONDUCTOR.

The first and most important consideration for long spans is the material of the conductor. Copper, aluminum, and iron are available for this purpose. Various alloys of copper have great strength, but their conductivity is too low and their cost too high to compare favorably with the more common metals. Copper wire varies widely in its characteristics, depending on the methods used in its manufacture. In general, the smaller the wire, the more it is worked and the better the result.

Cable made up of several strands has the advantage of using smaller wires than a solid conductor, and also permits of longer lengths of conductor without splices. Assuming a 300-lb. wire bar, a 19-strand cable for example can be made up weighing 5,700 lbs., while if solid wire were used the weight of one piece would be 300 lbs. In other words, there would be 19 times as many joints with the solid wire as with the 19-strand cable. The smaller the wire and the greater the strength, the more brittle it becomes. This is partially compensated for by the greater flexibility of a cable and the fact that a strand can break without the whole conductor parting.

Each strand should be a continuous wire without joints. Joints in the cable should be as few as possible and made by means of sleeves, as brazing or soldering anneals the wire and much reduces its strength. The permissible tension in the cable must not exceed the elastic limit, by which is meant the point at which the material will continue to elongate and will eventually break, and not the usually accepted meaning of elastic limit as that point at which the strain ceases to be proportional to the stress. Copper cable recently made for a transmission plant with spans of 500 ft. had an elastic limit of 40,000 lbs. per sq. in.; similar aluminum cable had an elastic limit of 12,000 to 14,000 lbs. per sq. in.; galvanized iron telegraph wire has an elastic limit of 35,000 lbs. The ultimate tensile strengths of these wires were 60,000 lbs. for copper, 24,000 lbs. for aluminum, and 55,000 lbs. for iron.

The advantage of aluminum is that it weighs less than copper for the same conductivity, but for long spans its lesser strength, greater diameter and higher coefficient of expansion are against it. Steel wire has about nine times and iron wire or cable about six times the resistance of copper, so that they are more expensive as a conductor than copper. In order to avoid oxidization it is necessary to galvanize iron or steel wire; this partially anneals it and reduces its strength. There are cases where the size of high-pressure line conductors is determined not by resistance, but by mechanical strength, and in such cases iron or steel wire can be used to advantage.

ELASTICITY.

The elasticity of the conductor is of considerable value in reducing the sag when the stress is removed, as will be shown later. The elongation of the wire under stress is less after it has once been stretched. The elasticity of cable is greater than that of solid wire, but both wire and cable take a set under any stress to which they may be subjected. In the following table is given the modulus of elasticity of copper, aluminum and iron wire:

Copper hard-drawn wire	19,500,000
Aluminum hard-drawn wire	10,200,000
Iron telegraph wire	24,000,000
Copper hard-drawn wire cable	16,300,000

Each sample was stretched to a point somewhat below its elastic limit before testing. It will be noted that the copper cable is considerably more elastic than the solid copper wire, the latter being a strand of cable. The aluminum wire was of nearly the same conductivity as the copper-wire strand, and presumably would have had a lower modulus of elasticity if made up into cable. Aluminum is considerably more elastic and has a decided advantage over copper in this respect.

COEFFICIENT OF EXPANSION.

The coefficients of expansion for Fahrenheit degrees are as follows:

Copper	0.0000096
Aluminum	0.0000013
Steel	0.0000064

As the worst condition so far as sag is concerned is reached when the conductor is hot, a low temperature expansion is most desirable for long spans, and steel is in this respect better than either copper or aluminum.

STRAINS IN CONDUCTORS.

The strains upon the conductor are those due to its own weight and the wind acting upon its surface. In a cold climate, sleet may form upon the wire, increasing the weight and the surface exposed to the wind. On a line carrying any considerable amount of power it is improbable that sleet will ever form on account of the losses in the conductor slightly heating it. In order to be on the safe side, however, it is best to assume in the north a coating of ice 1 in. thick all around the conductor. The wind velocity could never exceed 100 miles an hour, which would give a pressure of 40 lbs. per sq. ft. on a flat surface, or 20 lbs. on a cylindrical surface such as that of a wire. The weight is of course a vertical stress and the wind a horizontal one at right angles to the wire. The greatest strain is caused by the resultant of these two. The worst conceivable condition is sleet on the wire, followed by extreme cold weather with high winds.* Under such conditions the probabilities are that the ice on the conductor would break off, but without some data on the subject it is hardly safe to assume that this would be the case. In warm climates the absence of sleet and the lesser range of temperature make permissible longer spans than in cold climates.

SAG OF WIRE.

The maximum sag may be due to the conductor being loaded with sleet or to heating of the wire in a hot sun. The latter will generally be found to give the greater sag. Owing to the conductor being elastic it is not necessary to consider the greatest deflection from a horizontal line between supports as the vertical sag of the wire. The wind pressure causes the wire to swing to one side, and it is elongated by the combined strain of wind and weight, but as soon as it is relieved of the wind pressure it swings back to a vertical position and contracts to the length required to carry its weight alone. The sag due to heating of the wire is also somewhat less than it otherwise would be, because when expanded the strain is less and the wire contracts.

The extreme variation of temperature of the air in cold climates is about 150° F., while farther south it does not exceed 100° F. To this must be added something for a metal conductor exposed to a hot sun. There are no figures on record, but a total variation in the temperature of the conductor of 175° F. should be sufficient in any country.

HEIGHT OF TOWERS.

The height of towers is determined by the vertical sag and the clearance required above the ground. If a telephone circuit is below the transmission wires the distance between the telephone and power wires must be added. For instance, if the maximum sag is 12 ft., the telephone 6 ft. below the power wire and the clearance above the ground 20 ft., the tower must evidently support the wires 38 ft. from the ground.

INSULATORS AND PINS.

The insulators and pins must have sufficient mechanical strength to bear the strain transmitted to them from the cable. For example, in a 1,000-ft. span, the strain would be 980 lbs. per insulator 31° from the horizontal. A properly designed porcelain insulator will stand any strain that the pin will bear without bending. A rigid cast-iron or steel pin is therefore essential and can readily be obtained.

THE CROSS-ARMS.

The cross-arm is of course subjected as a beam to the weight and wind strains transferred to it from the cable, but in addition there is a torsional strain due to the breaking of a conductor that can best be borne by a pipe. The length of the cross-arm should be sufficient to space the wires well apart and prevent short circuits either from objects thrown over the line or from the wires swinging together. The former is the more important, and if a safe distance apart, say 6 ft. is chosen, it will be sufficient to guard against the latter, as on short spans with relatively less distance between wires they invariably swing together and never touch each other.

CONSTRUCTION OF TOWERS.

The most economical tower construction is one in which the spread of the legs at the ground is about one quarter to one third the height of the tower. If a less spread is used, the weight of the legs becomes excessive, and with a greater spread the cross-bracing must be much increased in size. For a single circuit the common windmill tower construction in which the legs are locked together at the top has the advantage of reducing the strains to a simple compression of the legs on one side and tension on the other, the only function of the cross-bracing being to prevent the legs buckling when in compression.

Where there are two or more circuits the length of the cross-arms is so great as to require two points of support. The tower can then be made with a width at the top approximating that at the bottom, and the cross-bracing has to bear its full share of the lateral strains.† A truss construction with the fewest number of parts and opportunities for slack motion and racking of the tower is preferable. Spreading the legs far apart obviates the necessity for expensive concrete foundations, as the strains can be made well within the limits which earth will stand in compression, and the weight of earth above the foot of the tower is sufficient to prevent its pulling out of the ground.

*Abstract of a paper read at the High-Tension Transmission meeting of the American Institute of Electrical Engineers at Chicago, June 21, 1904.

†Consulting Engineer, 49 Wall St., New York, N. Y.

*It was stated in the discussion that records show that very high winds rarely occur at low temperatures. At zero temperatures, the maximum velocity would be about 40 miles an hour.—Ed. Eng. News.

†Mr. Blackwell illustrated a tower composed of two steel A-frames parallel with the cables, and connected by transverse members carrying the insulators.—Ed. Eng. News.

A heavy galvanizing coating on the tower appears to be an effective protection against rusting and avoids the expense of painting.

To-day the highest pressure employed is 60,000 volts and the longest transmission is 150 miles. There is nothing to prevent the use of higher pressures and longer transmissions, provided reliability can be obtained by a more permanent, substantial, and simpler construction even if the expense is greater. The use of long spans and metal construction is a most important step in the right direction.

THE STRENGTH AND EFFICIENCY OF MIXTURES OF LIME AND CEMENT IN MORTARS.*

Mr. A. E. Black has investigated the subject of the strength and efficiency of the mixtures of lime and cement in mortars, which are now so often used in less important constructive work, especially in brick masonry of buildings. He says:

The commonly accepted theory among builders and architects is that while the mortar is weakened somewhat upon the addition of lime mortar to cement mortar, it is often cheaper to use the mixture than cement mortar alone (omitting lime mortar, used alone, from this discussion, for it does not answer the requirements of a good mortar). They argue that the mixture, being used in compression alone, is amply strong. The reasons for its cheapness are: (1) The lime mortar has bulk and thus increases the amount of mortar for a given quantity of cement. (2) The saving of time and thus of labor. The mixture becomes very pliable, and where a mason could take one trowel of cement mortar and spread it over one or two bricks at one time, he can take one trowel of the mixture and spread it over five or six bricks.

These arguments are very good from a builder's standpoint, but whether the cheapness of the mixture justifies the owner in accepting a mortar of reduced strength remains to be proved. In practice the mortar commonly called for by the architect is made as follows: Slake five bushels of lime and mix it with one load of sand of 32 cu. ft.; mix one part of Portland cement to three parts by weight of sand thoroughly in a dry state, then add a requisite quantity of water and mix thoroughly; equal quantities by weight of each of the above mixtures are well worked together.

From the experiments of the writer, the above mixture, a week old, stood a pressure of 25 tons per sq. ft., and increased in strength as it grew older. This proves that in brick masonry construction the mortar, as mixed by reliable builders, is amply strong, to take the pressure. In regard to the cheapness of the above mixture, 100 lbs. cost 11.49 cts. in St. Louis, using local prices of 1903, while the same amount of 1:3 cement mortar costs 16.77 cts., excluding the cost of mixing in both cases. This seemingly small difference amounts to hundreds of dollars on large buildings.

This mixture has good setting qualities, as proved by the writer's observations. It seems to take a little longer for its initial and final set, although finally it has a good set. In two buildings observed at time of construction, and one six months after, and another one year after the structure was completed, the set was very hard, for a nail could not be driven into the mortar joints at points tested in several stories of the buildings.

The writer has made nearly 800 tests (tension and compression) on thirty different mixtures of lime, cement and sand. A quantity of lime was slaked and the required amount of sand and water added, and then let stand for two days, when more water was added to compensate for that lost by evaporation. Lime mortar should be allowed to stand for a day or two to insure complete slaking and mixing. It has been found in practice that mortar used while warm does not give good results.

The cement mortar was mixed as soon as the lime mortar was ready. The cement mortar was mixed thoroughly in a dry state, and water was added and the mortar mixed again. The proportional quantities of each mixture were weighed out and given a final working with a trowel. This latter operation should be the most particular of all. The mixture was then put into the molds and allowed to stand for 24 hours, when a few of the tension briquettes were put into water, letting the rest remain in air for various lengths of time. The results are astonishing, showing that those in water stood about 100% more than those in air. This must be due to the cement in the briquettes; for the ones which contained mostly lime were very nearly the same in strength as those in air.

For the same age, the cement being constant, the tensile and compressive strength get less as the amount of lime increases.

This mixture one month old in compression stands a pressure of 850 lbs. per sq. in., and tension of 150 lbs. per sq. in., while neat cement stands for the tests 5,750 and 720 lbs. per sq. in. Lime alone stands for one month's age 93 lbs. in compression and 38 lbs. per sq. in. in tension, as was shown by Mr. Harting's thesis (Washington University, 1901).

Besides the general conclusions mentioned by Mr. Black, it may also be said that the effect of considerable age on the strength of such combinations is still unknown, and might be advantageously investigated by long-time tests.

*Abstract by Prof. J. L. Van Ornum of a graduating thesis by Mr. A. E. Black, of Washington University, St. Louis, Mo.

THE EXPORT OF MANUFACTURES in the fiscal year ending June 30 is the largest in the history of our foreign commerce. The Department of Commerce and Labor, through its Bureau of Statistics, has just issued a statement showing that for the eleven months ending with May, 1904, the total exports of manufactures aggregated in value $410,536,478. As this sum is about $17,000,000 in excess of the corresponding eleven months in 1900, it is very safe to estimate that the total for this year will be the highest in our history. For corresponding periods in other years, the values of exported manufactures in millions was as follows: 1888, 120 millions; 1890, 138 millions; 1896, 206 millions; in 1900, $393,089,574—the largest previous record. As noted by principal articles of export in the last year, iron and steel top the list with $100,267,566, a loss of nearly 10 millions as compared with 1900. Refined mineral oil came next in value, and then manufactures of copper, leather and cotton in the order named. The export of agricultural implements footed up $21,020,629, or nearly 7 millions more than in 1900; wood manufactures also gained over 2 millions in value. In fact, in nearly every article in the long list of exports there is a very marked gain in 1904, the only exceptions being iron and steel, tobacco and starch.

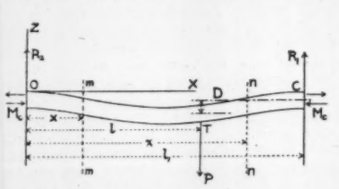

Fig. 1. Beam Fixed at Ends, Carrying Single Concentrated Load.

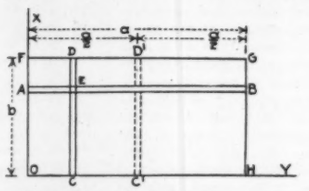

Fig. 2. Plan Diagram of Rectangular Plate Fixed at Edges.

AN APPRAISAL OF THE PRIVATE WATER-WORKS at Quincy, Ill., has been made by three engineers chosen by the city, instead of one chosen by the city, one by the company and a third by the two named. These works were owned by L. & W. B. Bull, under a franchise which expired in August, 1904. The franchise provided that in case of non-renewal at its expiration the city should buy the works at its then cash value. Mr. John A. Steinbach, Mayor of Quincy, was opposed to the usual plan of choosing appraisers and secured the appointment of three men, to be paid by the city. These men were: Messrs. Hiram Phillips, Chairman of the Board of Public Improvements, St. Louis, Mo., and John W. Alvord and Daniel W. Mead, both consulting engineers of Chicago. The owners of the works supplied the appraisers with all available information as to the value of the works, but did not agree in advance to accept the award. The engineers reported the value of the physical portion of the works, based on the cost of duplication, at the expiration of the franchise, as $614,355. From this they deducted $115,019 as depreciation and to the $499,336 thus resulting they added $149,823 of value as a going concern, making the net award $649,159. The owners of the property have given the city the option of taking the plant at the last-named price, provided it is done by Oct. 1, 1904. The finance and water committee of the city council has approved the award. Had the franchise stipulated a valuation at the time of the award instead of at the expiration of the franchise there would have been a difference of $50,000, due to the decreased cost of cast-iron pipe, in favor of the city.

THE STRENGTH OF FLAT PLATES, WITH AN APPLICATION TO CONCRETE-STEEL FLOOR PANELS.

By S. E. Slocum.*

The present monolithic construction attendant upon the use of reinforced concrete as a structural material, renders the determination of the distribution of stress in flat rectangular plates, fixed at the edges, of especial importance. In the following article there is developed a rational theory of such stress distribution, involving only elementary mathematical principles. The results obtained are then applied to the case of a concrete-steel floor panel in actual use.

It is first necessary to determine the deflection of a rectangular beam, fixed at both ends and bearing a single concentrated eccentric load, at the point of application of the load. Assuming such a beam, of dimensions given in Fig. 1, the reactions R_1 and R_2 are obtained as functions of the moments M_0 and M_c at O and C respectively, by taking moments about the neutral axis of the beam at O and at C. The differential equations of the two portions of the elastic curve are then obtained in the usual way by taking sections at m and n, and the constants of integration determined by means of the conditions $z = 0$ and $\frac{dz}{dx} = 0$ for $x = 0$ or l_1. At T both curves have the same ordinate and the same slope. This gives two simultaneous equations for M_0 and M_c. Inserting the values of M_0 and M_c so obtained in the equation of either portion of the elastic curve, the deflection D at T is the value of z for $x = l$. In this way it is found that

$$D = \frac{P l^3 (l_1 - l)^3}{3 E I l_1^3}. \qquad (1)$$

Now consider a loaded rectangular plate of length a and breadth b, with edges rigidly fixed at the same level, and let the co-ordinate axes be taken along two edges of the plate, as in Fig. 2. Then in order to find what proportion of the load at any point (x, y) goes to each pair of opposite edges of the plate, we suppose the plate divided by vertical planes into strips of small unit width parallel to the axes. Let P denote the load on the unit area at the intersection of two such strips (e. g., AB and CD in Fig. 2), and let V denote the amount of the load carried by C D and P — V the amount carried by AB. Then, if the width of the strips is small, we have from (1)

$$\text{deflection of D C at E} = \frac{V x^3 (b - x)^3}{3 E I b^3}.$$

and

$$\text{deflection of A B at E} = \frac{(P - V) y^3 (a - y)^3}{3 E I a^3}$$

Since the strips A B and C D are part of the same plate, their deflections at E must be equal. Consequently

$$\frac{V x^3 (b - x)^3}{3 E I b^3} = \frac{(P - V) y^3 (a - y)^3}{3 E I a^3}$$

whence

$$V = \frac{P b^3 y^3 (a - y)^3}{a^3 x^3 (b - x)^3 + b^3 y^3 (a - y)^3} \qquad (2)$$

Equation (2) gives the fraction of the load at any point (x, y) which is carried by the pair of edges parallel to the axis of Y; or, it may be considered as giving the load V at any point (x, y) of a strip of small unit width parallel to the axis of X.

For $y = 0$ or a, $V = 0$; while for $y = \frac{a}{2}$, $\frac{dV}{dy} = 0$ and $\frac{d^2V}{dy^2}$ is negative, which indicates a maximum. Therefore the cross loading is greatest at the center of the plate, and decreases to the value zero at either end. The cross strip carrying maximum loading is shown dotted in Fig. 2 as C′ D′.

In considering the distribution of loading on such a cross-strip, for constant P, i. e., uniformly distributed loading, we find that the roots of the equation $\frac{dV}{dx} = 0$ are: $= 0$, b, and $\frac{b}{2}$. If $x = 0$ or b, then $V = P$ and $\frac{d^2V}{dx^2} = 0$ which indicates a point of inflexion of the curve of loading; for the present case the actual maximum loading is found at this point. If $x = \frac{b}{2}$, then $\frac{d^2V}{dx^2}$ is positive, which indicates a minimum. Consequently, for any particular cross-strip, hence also for C′ D′, the load is a maximum at either end of the strip and a minimum at the center.

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Since the maximum moment in a beam fixed at the ends occurs at the abutments, the maximum bending stress in the plate must occur at the edges. In finding the amount of this maximum stress it is therefore allowable to consider any particular cross-strip (e. g., C' D' in Fig. 2) as an independent beam whose load line is given by equation (2), and find the maximum moment in the usual way. Since y = constant for any particular strip, we may put

$$b^3 y^3 (a - y)^3 = N \qquad (3)$$

in which case the equation of the load line becomes

$$z = \frac{P N}{a^3 x^3 (b - x)^3 + N} \qquad (4)$$

where z is used instead of V to denote the ordinate to the curve of loading measured perpendicular to the plane of X Y. The curve represented by equation (4) is shown in Fig. 4.

As the use of this septic would yield results too complicated to be of practical value, recourse is had to a simple curve which coincides closely with the given septic throughout the region under discussion. From equation (4) and Fig. 4, it is evident that the septic is symmetrical about a line through the center of the strip parallel to the axis of Z, and is convex downward. A parabola is the simplest curve of this shape, and can be made to approximate closely to the septic.

The equation of a parabola referred to its vertex as origin is $x^2 = m z$, or, if the vertex is the point (h, k),

$$(x - h)^2 = m (z - k).$$

If the axes are taken as in Fig. 3, the vertex is the point $\left(\frac{b}{2}, k\right)$; also if x = 0 or b, z = P. Substituting these values, $m = \frac{b^2}{4 (P - K)}$, and the equation of the parabola referred to O as origin becomes

$$\left(x - \frac{b}{2}\right)^2 = \frac{b^2}{4 (P - k)} (z - k). \qquad (5)$$

In this equation k, the ordinate of the vertex, is the value of V for $x = \frac{b}{2}$ from equation (2), that is,

$$k = \frac{P b^3 y^3 (a - y)^3}{b^3 y^3 (a - y)^3 + \frac{a^3 b^6}{64}}. \qquad (6)$$

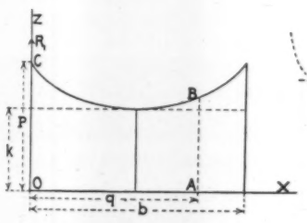

Fig. 3. Assumed Curve of Loading on Strip of Plate.

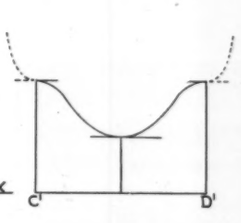

Fig. 4. Actual Curve of Loading on Strip of Plate.

In order to make the parabola fit more closely to the septic, the vertex of the parabola is kept fixed and the ordinates to the parabola at either end of the beam are increased from the value P to the value c P, where c is an arbitrary constant to be determined by trial. For the mid section of a square plate if c = 1.2 the error due to the use of the parabola instead of the septic is thus reduced to + .001 of the total area subtended by the septic, while for a rectangular plate of length equal to twice its breadth, if c = 1.06 the error is similarly reduced to — .001 of the total area. The value of c depends only on the ratio of the length of the plate to its breadth, and is independent of P or of the actual dimensions of the plate. Figs. 5 and 6 show the septic and parabola, plotted to the same scale, for the mid sections of a square plate and of a rectangular plate of length = twice breadth.

The distribution of stress in a strip of unit width, e. g., C' D' in Fig. 2, can now be determined. Let R_1 and M_1 denote the reaction and moment, respectively, at O (Fig. 3), and let the curve of loading be given by (5). Considering the portion of the beam on the left of any section A B, at a distance x from O, as a free body, the sum of the moments of the external forces about the neutral axis of the section gives

$$E I \frac{d^2 z}{d x^2} = M_1 - R_1 x + \text{Mom. of O A B C about A.} \qquad (7)$$

To find the moment of O A B C about A, let q denote the distance O A and x the distance from O to any point of O A. Then

$$\text{Mom. of O A B C about A} = \int_0^q (q - x) z \, dx$$

where z is given by equations (5) and (6), and P is replaced by 1.2 P. The integration gives

$$\text{Mom.} = \frac{c P - k}{6 b^2} (2 q^4 - 4 b q^3 + 3 b^2 q^2) + \frac{k q^2}{2}.$$

Considering the section A B as variable and replacing q by x, we have

$$\text{Mom. of O A B C about A} = \frac{c P - k}{6 b^2} (2 x^4 - 4 b x^3 + 3 b^2 x^2) + \frac{k x^2}{2}. \qquad (8)$$

From symmetry the reactions at the ends of the strip are equal. Consequently

$$R_1 = \frac{1}{2} \int_0^b z \, dx = \frac{b}{3} \left(k + \frac{c P}{2}\right) \qquad (9)$$

Substituting the values from (8) and (9) in (7), the latter becomes

$$E I \frac{d^2 z}{dx^2} = M_1 - \frac{b x}{3} \left(k + \frac{c P}{2}\right) + \frac{c P - k}{6 b^2} (2 x^4 - 4 b x^3 + 3 b^2 x^2) + \frac{k x^2}{2}. \qquad (10)$$

Integrating,

$$E I \frac{d z}{d x} = M_1 x - \frac{b x^2}{6} \left(k + \frac{c P}{2}\right) + \frac{c P - k}{6 b^2} \left(\frac{2 x^5}{5} - b x^4 + b^2 x^3\right) + \frac{k x^3}{6} + C_1.$$

If x = 0, $\frac{d z}{d x} = 0$ and therefore $C_1 = 0$; also if x = b, $\frac{d z}{d x} = 0$ and therefore $M_1 = \frac{b^2}{60} (c P + 4 k)$. Substituting these values in the above equation and integrating, the constant of integration is determined by the condition z = 0 for x = 0, and the equation of the elastic curve becomes

$$E I z = \frac{b^2 x^2}{120} (c P + 4 k) - \frac{b x^3}{18} \left(k + \frac{c P}{2}\right) + \frac{c P - k}{6 b^2} \left(\frac{x^6}{15} - \frac{b x^5}{5} + \frac{b^2 x^4}{4}\right) + \frac{k x^4}{24}. \qquad (11)$$

From this the deflection, d, at the center, is found to be

$$d = \frac{b^4}{5760 E I} (2 c P + 13 k) \qquad (12)$$

If p denotes the maximum unit fiber stress and e the distance of the extreme fiber from the neutral axis, equation (10) can also be written

$$\frac{p I}{e} = \frac{b^2}{60} (c P + 4 k) + \frac{c P - k}{6 b^2} (2 x^4 - 4 b x^3 + 3 b^2 x^2) + \frac{k x^2}{2} - \frac{b x}{3} \left(k + \frac{c P}{2}\right).$$

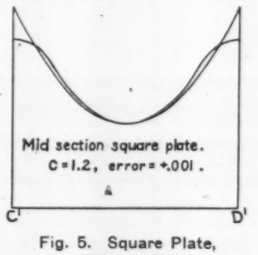

Fig. 5. Square Plate, Mid-section.
C = 1.2; error in area of load curve = + .001.

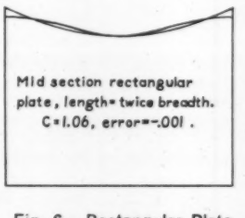

Fig. 6. Rectangular Plate, Length equal to Twice Breadth, Cross-Section at Middle.
C = 1.06; error in area of load curve = .001.

from which

$$p = \frac{e}{I} \left\{ \frac{b^2}{60} (c P + 4 k) + \frac{c P - k}{6 b^2} (2 x^4 - 4 b x^3 + 3 b^2 x^2) + \frac{k x^2}{2} - \frac{b x}{2} \left(k + \frac{c P}{2}\right) \right\} \qquad (13)$$

For a maximum or minimum value of p, $\frac{d p}{d x} = 0$.

In the present case the equation $\frac{d p}{d x} = 0$ reduces to

$$(2 x - b) [(c P - k) (2 x - b)^2 + 3 b^2 k] = 0$$

Two roots of this cubic are imaginary, while for the real root, $x = \frac{b}{2}$, $\frac{d^2 p}{d x^2}$ is positive, which indicates a minimum. But this is the criterion for a calculus minimum, and in this case simply means that the moment has its greatest *negative* value at the center of the strip. The reason why the criterion gives no real maximum value of p under the assumption of parabolic loading is because the parabola recedes indefinitely from the origin. However, the actual maximum for the case under consideration occurs when x = 0 or b, as may be easily verified, and consequently

$$p \text{ max.} = \frac{e}{I} \left[\frac{b^2}{60} (c P + 4 k)\right] \qquad (14)$$

Since it has previously been shown that the cross loading is greatest for a strip through the center of the plate, the value of k in (14) is found from (6) by putting $y = \frac{a}{2}$, whence

$$k = P \frac{a^3}{a^3 + b^3} \qquad (15)$$

In the derivation of equation (14) it was necessary to consider the width of each strip as very small. In applying the formula, however, this restriction is no longer necessary, and any convenient units may be chosen for substitution in the formula. It is also to be especially noted that for a homogeneous plate the quantity I in (14) is the ordinary moment of inertia of a cross section of any strip about its neutral axis; but for a composite plate, such as a concrete-steel floor panel, I is the moment of inertia of a cross section of an equivalent homogeneous strip about its neutral axis. That is to say, if E_c and E_s are Young's moduli for concrete and steel, respectively, in order to find I the area of the steel is increased in the ratio $E_s : E_c$; or, since the distance of any particle from the neutral axis must remain unchanged, the breadth of that portion of the section in which the steel occurs is increased in this ratio. The cross section obtained in this way is called the equivalent homogeneous section, and its moment of inertia may be obtained by the ordinary methods.

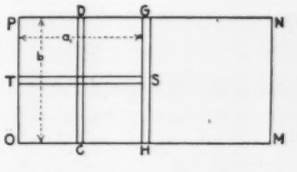

Fig. 7. Plan of Rectangular Plate with Intermediate Girder.

Thus far the analysis has been based upon the assumption that the edges of the plate were rigidly fixed to inflexible supports. In the structural use of flat plates, however, this assumption is often vitiated by the plate being built into girders which themselves deflect under the load. In the case of rectangular floor panels there often enters still another element of uncertainty by reason of their being divided into smaller panels by intermediate girders of less section, and consequently of greater deflection, than the main gir-

ders. It is necessary, therefore, to determine how these various conditions will affect the results of the preceding analysis.

Since it has been proved that the maximum stress in a flat plate occurs in a cross section through the center, it is only necessary to consider how the loading on such a section is affected by the deflection of the supports. For a rectangular plate supported by girders of uniform cross section (Fig. 7), the deflection at the middle points, G and H, of the longest sides is greater than at any other point of the perimeter. Consequently the amount of load carried by G H due to a unit load at any point of G H is less than if the supports were rigid. For a square plate the load at the middle of a cross strip through the center of the plate is the same as if the supports were rigid, but at every other point of the strip is less than if the supports were rigid. Consequently, for both square and rectangular plates the deflection of the supports tends to decrease the maximum stress below the value given by equation (14).

For a rectangular panel subdivided by an intermediate girder through its center, the problem of the distribution of stress is indeterminate; for the deflection of the supports can not be determined until the load resting on them is known, and the amount of this load cannot be calculated until the distribution of stress in the panel is known, which involves the deflections. However, an approximate solution of the problem can be given, and a limit to the maximum value of the stress determined, as follows:

If the ends of the cross girder G H are built into the longitudinal girders O M and P N (Fig. 7), it must deflect with the latter, and, consequently, the deflection of O H and P G below a plane through the four points O, P, G, H will be slight. Therefore, in order to make the problem determinate, it will be assumed in considering the half panel O P G H that the deflections of P G and O H are zero, and it will also be assumed that P O and G H have the same cross section, the section chosen being the smaller of the two, provided there is any difference. Each of these assumptions will have the effect of slightly increasing the loading of O H and P G, and thus give a calculated maximum stress somewhat greater than the actual maximum stress. The problem is thus reduced to that of a flat plate fixed at two edges, O H and P G, to inflexible supports, and at the other two edges, O P and H G, to flexible supports of equal rigidity.

The first step in the approximate solution is to calculate the load on the supports regarding these supports as inflexible, and then calculate the deflection of O P and H G under this loading. Let a_1 and b denote the dimensions of O P G H, as in Fig. 7. Then, by equation (9) the load at any point of O P or H G, due to a panel load on one side of the girder, is

$$R_1 = \frac{a_1}{3}\left(k_1 + \frac{c\,P}{2}\right). \qquad (16)$$

where

$$k_1 = \frac{P\,a_1{}^2\,x^3\,(b-x)^3}{a_1{}^3\,x^3\,(b-x)^3 + b^3\,a_1{}^3}. \qquad (17)$$

If the panels on opposite sides of O P and H G are equal in dimensions and loading, the total load at any point of O P or H G is $2R_1$. Therefore if the origin is taken at the left end of O P or H G, the axis of X along the girder and the axis of Z perpendicular to the plane of the plate, the curve of loading of O P or H G is represented by the equation

$$z = \frac{P\,a_1}{3}\left[\frac{64\,x^3\,(b-x)^3\,(2+c) + c\,b^3\,a_1{}^3}{64\,x^3\,(b-x)^3 + b^3\,a_1{}^3}\right]. \qquad (18)$$

The roots of the equation $\frac{dz}{dx} = 0$ are $x = 0, b, \frac{b}{2}$; for $x = 0$ or b, $\frac{d^2z}{dx^2} = 0$, which indicates a point of inflexion; while for $x = \frac{b}{2}$, $\frac{d^2z}{dx^2}$ is negative which indicates a maximum. Consequently the load is a maximum at the center and a minimum at either end of the girder, the curve of loading being concave toward the axis of X, like Fig. 4 inverted. If Q denotes the ordinate to the curve of loading at either end of the beam and k_2 the ordinate at the center, then, by considerations similar to those which precede, this curve can be replaced by the parabola

$$\left(x - \frac{b}{2}\right)^2 = \frac{b^2}{4\,(Q - k_2)}(z - k_2).$$

In this equation Q is the value of z from (18) for $x = 0$ or b, and k_2 is the value of z for $x = \frac{b}{2}$, whence

$$Q = \frac{a_1\,c\,P}{3}, \qquad (19)$$

and

$$k_2 = \frac{P\,a_1}{3}\left\{\frac{(2+c)\,b^3 + c\,a_1{}^3}{b^3 + a_1{}^3}\right\} \qquad (20)$$

The deflection at the center of a beam fixed at both ends and loaded in this manner is found to be

$$\delta = \frac{b^4}{5760\,E\,I_1}(2\,Q + 13\,k_2), \qquad (21)$$

where I_1 is the moment of inertia of a cross section of the beam about its neutral axis.

Returning to the plate itself, the section of maximum loading in the half panel O P G H is midway between, and parallel to, O P and H G. Let k_a denote the mid ordinate to the curve of loading of T S, and P-k_a the mid ordinate to the curve of loading of D C. Then from (12)

$$\text{deflection at center of T S} = \frac{a_1{}^4}{5760\,E\,I}\left[2\,c\,P + 13\,(P - k)\right]$$

and

$$\text{deflection at center of D C} = \frac{b^4}{5760\,E\,I}\left[2\,c\,P + 13\,k_a\right].$$

Therefore since δ from (21) is the deflection of O P and G H at T and S,

$$\frac{a_1{}^4}{5760\,E\,I}\left[2\,c\,P + 13\,(P - k_a)\right] + \delta = \frac{b^4}{5760\,E\,I}\left[2\,c\,P + 13\,k_a\right]$$

whence

$$k_a = \frac{P\,a_1{}^4\,(2\,c + 13) - 2\,c\,P\,b^4 + 5760\,E\,I\,\delta}{13\,b^4 + 13\,a_1{}^4}. \qquad (22)$$

Consequently the maximum value of the unit stress becomes

$$p\ \text{max.} = \frac{c}{I}\left[\frac{b^2}{60}(c\,P + 4\,k_a)\right]. \qquad (23)$$

To illustrate the application of the above formulas, they will now be used in the calculation of the maximum stress in a concrete-steel floor panel, the example chosen being one of the floor panels in the seventeen-story concrete-steel office building described in Engineering News of July 30, 1903. The dimensions of the main floor panels in this building are 16 ft. × 32 ft., subdivided by an intermediate girder into two panels, each 16 ft. × 16 ft. The live load is assumed to be 60 lbs.-ft.^{2}, and the dead load, due to the weight of the floor slab, is also 60 lbs.-ft.^{2}, making a total live and dead load of 120 lbs.-ft.^{2}.

Formula (14) will first be applied to one of these square panels. The thickness of the floor slab is 5 ins., and the concrete is reinforced by ¾-in. twisted square steel rods, laid in two layers at right angles, and spaced 1 ft. apart. With this spacing the width of the strip considered must be taken to be 12 ins. in order to include one rod. Since the concrete is assumed to carry only compressive stress, the effective depth of cross section of any strip is the distance from the top fibre of concrete to the bottom fibre of steel. Taking then the upper layer of rods as giving the least moment of inertia, and choosing a section in which the sides of the rods are parallel to the sides of the beam, the effective depth of cross section = 3.79 ins.

The ratio between the moduli of elasticity of steel and concrete in tension will be taken as $E_s:E_c = 28:1$*. Increasing the area of the steel in this ratio and keeping its depth constant, viz., ¾-in., the breadth of that portion of the equivalent homogeneous section containing the steel = 21 in. The distance of the neutral axis of the ⊥-shaped section so obtained below the top surface of the beam is found to be e = 2.091 in., and the moment of inertia of the section about its neutral axis is I = 68.43 in.^{4} Noting that P is the load per linear unit of the strip chosen, in the present case = 10 lbs.-linear in., and using c = 1.2, the substitution of the above values in (14) gives

$$p\ \text{max.} = \frac{2.091}{68.43}\left[\frac{(192)^2}{60}(12 + 2.4)\right] = 600.8\ \text{lbs.-in.}^2$$

If the deflection of the supporting girders is taken into account, the approximate solution outlined above is as follows: The value of c is calculated for the intermediate girder since it is of less cross section than the girders parallel to it at either end of the panel. The depth of this intermediate girder is 18 ins., its breadth is 12 ins., and it is reinforced by two 1-in. twisted square steel rods near its lower face. Increasing the area of the steel in the ratio 28:1, it is found that for the equivalent homogeneous section the distance of the neutral axis below the upper surface of the girder is e_1 = 9.92 in., and the moment of inertia about this neutral axis is I_1 = 7230 in.^{4} Since the length of the girder is a_1 = 192 in., c = 1.2 and $P = \frac{120}{144}$ lbs.-in.^{2} we have from (19) and (20), Q = 64 lbs.-linear in., and k_2 = 117.3 lbs.-linear in. Substituting these values in (21), we find that the deflection at the center of the intermediate girder is δ = .045 in.

As a matter of fact, the deflection will be less than this value, for in order to allow for the reversal of stress near the ends of a beam fixed at both ends these girders have an extra reinforcement of rods near the top surface and extending part way into the girder from each end, thus making the moment of inertia greater nearer the ends than at the center. However, it is on the side of safety and sufficient for the purpose of this example to calculate the deflection δ under the assumption of uniform moment of inertia throughout the girder.

Substituting the values just obtained in (22), we have k_a = 5.6 lbs.-linear in., and therefore, from (23), p max. = 645.8 lbs.-in.^{2} Consequently the maximum effect of the deflection of the supports is, in the present case, certainly not greater than 45 lbs.-in.^{2}, or 7½ per cent, of the maximum stress calculated under the assumption that the supports are inflexible.

The maximum shear is the value of R_1 from (9) for a strip through the center of the plate. For such a strip, one foot wide, we have P = 10 lbs.-in., k = 5 lbs.-in., c = 1.2, and b = 192 in.; consequently R_1 = 704 lbs. If the deflection of the supports is taken into account, the value of k in (9) must be replaced by that of k_a from (22). In this case the maximum shear becomes R_1 = 742 lbs. This is distributed over an area of concrete and steel equivalent to 52 in.^{2} of concrete, giving a shearing stress in the first case of 13.5 lbs.-in.^{2} and in the second case of 14.3 lbs.-in.^{2}

In the article from which the present example is taken, it is stated that "the panels are figured as a flat floor slab supported on four edges." If, however, the panels are assumed to be fixed at the edges, as in the above discussion, a reversal of stress occurs near the edges of the panel which necessitates reinforcement near the top surface of the floor slab. The point where the reversal of stress occurs is determined by finding the point of inflexion of the elastic curve of a cross strip. Thus, from (11) by putting $\frac{d^2z}{dx^2} = 0$, it is found that this point of inflexion always lies at a distance $< \frac{b}{4}$ and $> \frac{b}{8}$ from the edges of the plate, its exact location within these limits depending on c, P and K. Therefore the reinforcement near the top surface of the floor slab should extend inward from the edges to a distance not less than one-fourth the width of the panel.

*Johnson: Materials of Construction, p. 72.